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Price Volatility, Nonlinearity and Asymmetric Adjustments in Corn, Soybean and Cattle Markets: Implication of Ethanol-driven Shocks

by

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Price Volatility, Nonlinearity, and Asymmetric Adjustments in Corn, Soybean, and Cattle Markets:

Implications of Ethanol-Driven (Market) Shocks

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Price Volatility, Nonlinearity and Asymmetric Adjustments in Corn, Soybean and Cattle Markets: Implication of Ethanol-driven Shocks.

Grain prices have risen sharply since 2005 and 2006 affecting livestock markets by increasing feed prices and leading to significant volatility shocks. The high price levels and magnitude of sustained high volatilities has raised concerns for many sectors of the economy, in particular those with direct relation to these markets. Policy makers are analyzing the interrelationships among these markets, and the effects of energy market shocks on agricultural markets. This study considers a threshold structure in a multivariate time-series model that evaluates these market linkages, capturing asymmetric correlations between grain and livestock prices, including volatility spillovers. We empirically study the impact of corn usage for ethanol production in the evolution of the above mentioned prices. Results are compared to previous scenarios where corn, soybean and livestock production and consumption did not face the corn demand for ethanol production. We find positive dynamic correlations between corn and soybean and feeder and fed cattle prices, consistent with the literature. And we find an inverse or negative relation between corn and feeder/calf prices for the period post mandated ethanol production, as anticipated by the literature for increased corn prices. Also, we find there are adjustment costs inhibiting price transmission between the crops and the live cattle market, in the form of modifying feeding rations. More relevantly, we identify plausible asymmetric effect on the correlations between the markets, especially when considering the period for the ethanol driven corn consumption versus previous periods of corn consumption. These asymmetric correlations are the result of spillover effects.

Key words: price volatility, market linkages, thresholds, ethanol-driven shocks, asymmetric correlations, spillovers.

Introduction

Grain prices have risen sharply from 2006 onwards – approximately two-fold in the case of corn, and also for soybeans. This has also affected livestock markets by increasing prices and leading to significant volatility shocks, since more than half of the corn production is used as animal feed and soybeans remain an important feed source. The high price levels and magnitude of sustained high volatilities raise concerns for many sectors of the economy – consumers facing higher food prices, and producers facing unprecedented levels of price uncertainty coupled with higher input prices. Policy makers are analyzing the interrelationships among these markets and the effects of energy market shocks on agricultural markets. See Appendices 1, 2 and 3 for charts of futures prices, historical volatilities and also for implied volatilities of these commodities respectively.

Increasing grain commodity prices coupled with changes in their volatility, has implications for many decision makers. In our study, agents that have a direct relation with grain markets - specifically corn and also with soybeans (oilseed), are particularly affected by these price variations. Crop producers are influenced in their planting decision making - to grow either corn and/or soybean seeking to obtain better profitability, considering that corn production involves higher input costs than soybeans. At the same time, livestock producers require these crops as input, having their costs and profitability directly affected by the change and volatility in these input prices. These agents benefit from an appropriate determination of the dynamic

interrelationships among these markets, as it may lead to efficiency gains in their operation. In addition, policy makers need to determine the impact that recent energy policies – directly affecting corn consumption, are having on the prices and markets related with this grain.

This paper considers time-series models that evaluate market linkages between corn, soybean and cattle prices – both feeder and fed cattle. By using a threshold structure in a multivariate time series model we are able to capture asymmetric correlations between grains and livestock prices, including volatility spillovers. These volatility spillovers are characterized by the resulting persistence of markets staying at certain correlation levels. In addition, we recognize potential inhibition in the transmission of prices between markets, which may be the result of adjustment costs between them.

We empirically analyze the impact of corn usage for ethanol production in the evolution of the above mentioned prices. We calculate the dynamic correlations between corn, soybeans and feeder and fed cattle for two separate periods, including the latest period where corn faced a consumption boost from ethanol production. Results of this latter period are compared to previous periods where corn, soybean and cattle production did not face the corn demand for ethanol production, mandated from energy policy acts. Implications for how these commodity markets are linked to one another are discussed. Risk spillovers from one market to another are identified, and their impacts on market interrelationships are discussed.

Results obtained are consistent with past literature in that we find positive dynamic correlations between corn and soybeans and between feeder cattle and live cattle, for both periods calculated - pre and post mandated ethanol corn consumption. We also find no significant correlation between either crop prices – corn and soybeans (used as feed) and live cattle markets, for both periods considered. Thus we denote a threshold or adjustment cost in the form of modifications of feed rations, preventing the transmission of increases in these crop prices to the live cattle prices. We also find inverse or negative dynamic correlations between corn and feeder cattle only for the period of post mandated ethanol consumption. This is also consistent with previous literature, where increases in prices of corn produce a decrease in price of feeder cattle. In addition, we identify a significant underlying factor – the change in the harvest price ratio of soybeans to corn prices, which has a role on spillover effects between the markets. Results previously mentioned are followed by discussion of the findings, and implications for dynamic relations between the markets.

The paper proceeds by providing a general review of the relation between corn and ethanol, then describes the characteristics of grain markets, and details the particular context of the corn market. We then provide a brief literature review of studies that include the impact of corn used for livestock feed, on cattle profitability. Also previous studies regarding market linkages and price transmission, including asymmetric price adjustments in different cattle and pork markets are addressed. Subsequently we present the parsimonious version of the Regime Switching Dynamic Correlations model, which calculates correlation values between the markets considered - that are proportional to each particular regime. In this study we consider two different regimes hence there will be two different correlation levels - proportional to each other, for each market pair considered. e.g. the correlation values between corn and soybeans for each regime are proportional to each other, also the correlation values between corn and feeder cattle in each regime are proportional to each other, and so forth. The switches between regimes are governed by a Markov chain, using constant transition probabilities. We extend the parsimonious

model by introducing state dependent transition probabilities between the two different regimes considered. These new transition probabilities take into account specific underlying fundamental variables related to the evolution of the markets, which may capture asymmetries in these dynamic correlations. Hence analysis of shocks of these variables may be obtained, studying the impact of spillover effects. The initial model's constant transition probabilities become a nested case of our extended model. Also, by including these state dependent transition probabilities between regimes our model may provide a more accurate representation of the dynamic process. In addition, improved forecasting is obtained when considering these relevant underlying variables.

Background

The relation between ethanol fuel production and use of agricultural commodities in the U.S., specifically in our case corn, began regularly in the early 1900's (with the model T from Ford), yet its production was strengthened after Congress passed The Energy Tax Act of 1978. This act stated that for gasoline mixtures that included at least 10% ethanol content, there would be an exemption on the federal excise tax (i.e. subsidy) of 40 cents per gallon of ethanol mixed with gasoline. During the 1980's this tax exemption increased up to 60 cents per gallon of ethanol with the Tax Reform Act of 1984, settling at 54 cents in 1988. Ethanol was mainly used as an oxygenate agent in the mix of gasoline production, yet trailed distantly MTBE (Methyl Tertiary Butyl Ether) - which dominated the market, made from natural gas and petroleum. In 2004, this latter component had been banned from almost all states, as the EPA declared in 2000 that its use should be gradually discontinued.

Ethanol faced a boost in demand with the previous MTBE ban and also with the Energy Policy Act of 2005, which mandated an increase in the use of renewable source of fuel energy – mainly ethanol. The act called for a doubling of ethanol use by 2012. Recently, in 2007 Congress passed the Energy Independence and Security Act, which augmented the Renewable Fuels Standard to require that 36 billion gallons of ethanol and other fuels be blended into gasoline, diesel, and jet fuel by 2022. Current ethanol production stands at seven billion gallons per year and mandated to reach 13 billion gallons by 2012 and 15 billion gallons by 2015. This enormous increase in ethanol production from corn in recent years has led to hikes in corn prices and acreage. Acreage land for corn production has been taken away mainly from soybean production, as these grains have similar requirements of production conditions. This has consequently lowered soybean production, having an effect in the increase of soybean prices. A record use of corn acreage leading to a record harvest output was obtained in 2007. This past 2008 had a slight drop in corn acreage in favor of soybean production.

Regarding the grain commodities market, there are three characteristics that distinguish this market versus that of other commodities, as noted by Schnepf (2006). There is seasonality inherent in the production period. That is crop producers make their production decisions based on ex-ante information or expectations about their anticipated yield, hence regarding the price of the inputs as well as the harvested crop. A second characteristic is that the demand for these grains is generally of derived nature. In other words, a majority of the grains may be used as input for processing a different final product, in this case - more than half of total corn production is used as a major component of feed for livestock. Finally, the nature of the supply

and demand aspect is that it is generally price-inelastic, especially for grains. That is, small movements in supply generate large price swings.

With respect to grains, specifically corn, the U.S., China, and Brazil account for 2/3 of the world's production. Of the three, the U.S. is the largest exporter, covering approximately 2/3 share of the world market with about 18% of its production. Since 2000, approximately 58% of the U.S. corn production has been used as the primary energy source of feed for live-stock. The remaining 24% of production is used for food and industrial products such as starch, sweetener, fuel ethanol, corn oil and others.

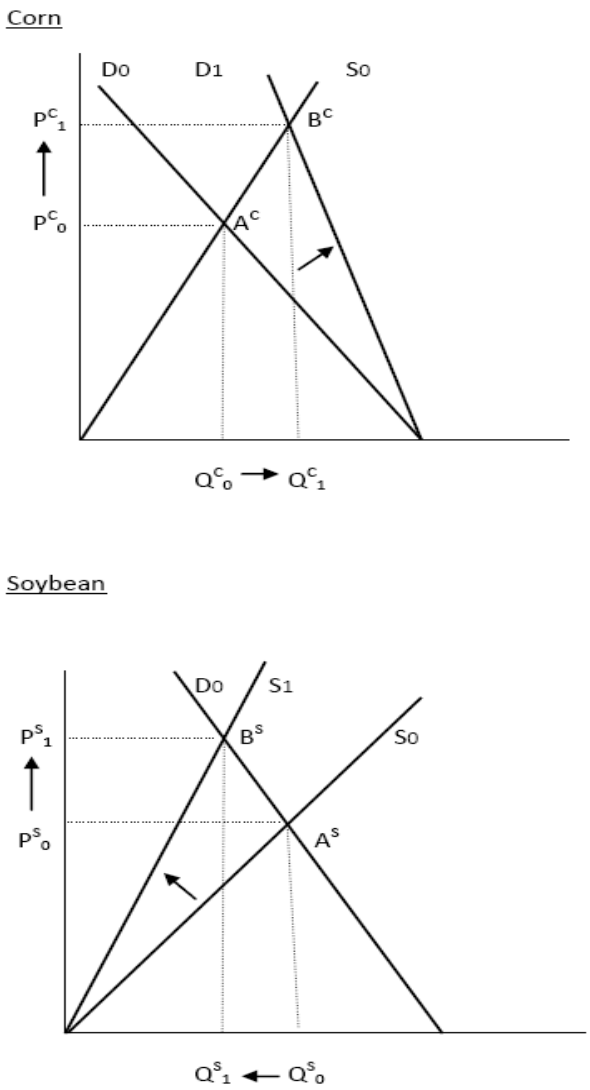
With data from the Foreign Agricultural Service of the USDA, Westhoff (2008) notes that between the marketing years of 2005/2006 and 2007/2008, there was a rise of 35 million tons in U.S. corn consumption attributed only for ethanol production. This accounted for about 43% of the increase in total world grain consumption, which if excluded, would have grown around 2 to 2.5%, i.e. being very similar to world population growth. Furthermore, previous to 2005 there has been a regular average increase around 2% in total world grain consumption, dating back to 2000. i.e., recent hikes in corn consumption beyond this rate of world population growth may be attributable for use in the production of ethanol.

Corn is the most broadly produced feed grain in the U.S., encompassing more than 90% of the total value and production of all feed grains. Corn feed competes with other feed grains – soybean, grain sorghum, barley and oats, as well as feed wheat and in some instances lower-priced protein meals. Feed grain markets are sensitive to relative prices among these different feed components.

The 2005 Energy Policy act, and subsequently the 2007 Energy Independence and Security act, generated a significant increase of ethanol production resulting in a substantial rise in the demand for corn, as noted previously by Westhoff (2008). These policies produced an outward shift in the curve of corn demand – main input material being used for ethanol production, resulting in a higher amount of corn being supplied at a higher price. This higher amount of corn production affected the soybean market, which shares a common geographical production area with corn, by transferring acreage to growing corn which had been previously used to produce soybean. This lower production of soybean has also resulted in a higher price of soybeans. At the same time, both these crops serve as feed for livestock markets, having a possible effect on the price and profitability of these markets.

A chart depicting the relations between corn and soybeans may be seen in Figure 1. The price elasticity of supply for corn is anticipated to become more inelastic as the demand for corn increases, raising the price of corn. In addition, the price elasticity of supply for soybean also becomes more inelastic, as its supply decreases from transferring acreage from soybeans to corn production.

Figure 1.



Each year crop producers of corn and soybeans begin to assess their acreage decision for the next growing season, following the present grains' harvesting period. When analyzing their decision, producers consider a ratio of harvest date prices for soybeans and corn to be around 2.2 to 2.4 - equal to a Break Even Price Ratio (BEPR). The value for this ratio is such that producers do not favor the production of one crop over the other. This BEPR ratio takes into consideration input requirements for each grain, as well as their different yield per acre, and other related expenses as per Lin & Riley (1998). The prices of the ratio are for harvest periods, i.e. December contracts for corn and November contracts for Soybean. The ratio is checked by producers previous to the planting season, i.e. during December, January and February, including initially March in order to make a decision and subsequently plant the crop. Ratio variability within this previous planting period may modify producers' decision to opt for planting corn instead of soybean, when for example the ratio is lower than two.

The dynamic relations between the crop prices, specifically corn and soybean - which are considerably correlated, and also with livestock prices is important to capture in order to obtain

significant efficiencies with respect to each operation. Our threshold structure depicts the non-linear relation present in these markets through the calculation of dynamic asymmetric correlations. It makes use of state dependent (time varying) transition probabilities, specifically incorporating underlying related factors to these markets in the process, to switch among regimes of different correlation between the markets considered.

Market linkage and transmission of prices between grains and cattle markets are subject to transaction costs, resulting in instances where price variations are not passed on directly between markets but subject to certain adjustments. These adjustment costs may be different in the case of positive shocks than negative shocks. i.e. a price increase may be not transmitted in an equal inverse form if it is a price decrease, thus generating asymmetries, or the adjustment cost may result in a threshold where the price is not transmitted at all between markets.

Our study analyzes the dynamic correlations present between corn, soybean, and cattle livestock considering the hike in price and volatility of this grain and oilseed on the livestock prices, as both corn and soybean are main feed components for livestock and corn has been especially affected by the increase in its demand for ethanol production. Specifically, the effect of price volatility on cattle feed rations may be assessed from these grain and livestock correlations. In this sense, we anticipate feed rations of livestock to change in response to variances in the prices of corn and soybean. Additionally, the resulting higher cost of corn feed is anticipated to have an inverse relation effect on feeder cattle price, consistent with the literature.

Next we review corn, and studies of its incidence on livestock feed for cattle profitability. Also previous studies regarding market linkages and price transmission, including asymmetric price adjustments in different cattle and pork markets is addressed. Subsequently, we present the parsimonious version of the Regime Switching Dynamic Correlations model, and introduce state dependent transition probabilities between two different regimes considered. Results are followed by discussion of the findings and implications for dynamic relations between the markets.

Literature Review

There have been numerous studies analyzing the incidence of corn price in its relation to livestock profitability, since it is the main source of feedstock. In cattle production profitability, a study by Langemeier et al. (1992), using monthly average data for 2600 pens from 1980 through 1989, concluded that in addition to cattle feeder and cattle fed i.e. live cattle prices, changes in corn prices had an approximate 22% impact in the variability of profits. Another study by Schroeder et al. (1993) using larger individual pen level data from almost similar period (1980 to mid 1991), found that corn price changes impacted between 16% and 6% of cattle profit risk - decreasing as cattle placement weight increased, i.e. the weight of the feeder cattle. A study by Mark et al. (2000) for cattle profitability from 1980 to 1998, also considering two feedlots in Kansas showed similar results. That is corn prices have a lower incidence in cattle production profit risk than both calf and live stock prices.

Lawrence et al. (1999) analyzed more than 200 feedlots over a much broader space area located in the corn belt, including Illinois, Iowa, Minnesota, Nebraska and South Dakota (not just two

feedlots in Kansas as previous studies) and found that corn prices, while still significant for cattle production profitability, had less impact than feed efficiency and average daily gain. These results were obtained considering corn from 1987 to 1996, where prices fluctuated from slightly under $2 to almost $5 per bushel.

Another study by Albright et al. (1994) specifically determined that about 60% of variability in cost of weight gain (i.e. feed efficiency) could be attributed to corn price variability. This analysis of the cost of gain was obtained from data of two Kansas feedlots, considering corn prices from 1980 to 1991

A different study by Anderson and Trapp (2000) for the feeder cattle market, estimates a dynamic corn price 'multiplier' that simultaneously impacts placement weight, slaughter weight and feed-conversion rate as the price of corn changes. This dynamic effect is taken into account in a cost/revenue setting, such that the break-even feeder cattle price may be determined. Results indicate that increases in corn prices are mitigated by changes in feeding programs or compositions, producing a smaller decline of calf-feed prices.

A recent paper by Belasco et al. (forthcoming) studies the dynamic relations between cattle production yield risk factors, including the influence of cattle pen characteristics, in assessing the risks borne by cattle producer's profits - using a dynamic multivariate regression model. The price of feed, including corn, may be indirectly considered as part of a yield risk factor (dry matter feed conversion & average daily gain – i.e. 'cost' of gain) and the dynamic effect of this factor is estimated. Also, as mentioned by Lawrence et al. (2008) – the monthly survey of commercial cattle feedlots by Kansas State University points out that the cost of gain has risen from an approximate average of 54 cents per lb. in 2006 to 74 cents in 2007, to over 80 cents per lb. in 2008.

Regarding the sharp increase in food commodity prices including grains such as corn and soybean, during the last couple of years - an extensive report detailing major factors was presented by Trostle (2008). In the report he states that recent global increases in demand of feedstock for biofuel – mentioned previously with respect to ethanol, along with a decline in the U.S. exchange rate have been relevant demand factors contributing to a hike in price. In addition supply factors such as increasing energy prices - as crude oil prices rise, higher input production costs, and adverse weather - have also contributed.

Another report by Schnepf (2008) also contends that coarse grains – mainly corn though also barley, sorghum, oats and rye, have faced increased demand due to two major factors. One factor is through feed use for livestock due to increased demand for meat from India and China (as these two large countries experience high income growth). Another larger factor is through input for biofuel production rising from policy mandates, both here in the U.S. as well as in Europe.

Our study estimates the dynamic correlations and volatilities between crop prices – corn, soybean and livestock prices, via a regime-switching dynamic correlations model; determining the effects of the increased demand for corn from ethanol production on these markets. Spillover risks from one market to the other are analyzed and discussed, as well as implications for long-run risk and price levels.

Market linkages of these grain and cattle markets are analyzed by studying the adjustment between these markets for cases of price changes. The markets may respond to transmission of price variations by fully passing them along, or by having adjustments according to transaction costs that are present between the markets. In some instances these markets may be related production wise, as in the case of corn and soybean in the U.S. In other cases, these markets may be vertically related, as in the case of corn used as main feedstock component for cattle production. In either situation it may be that there are negligible adjustment costs such that market price variations may be passed on concurrently to another market, or it may be that there are significant adjustment costs which delay the transmission of price changes – perhaps generating spillover effects.

Several studies have been conducted regarding asymmetric price adjustments, including threshold behavior. A paper by Goodwin and Holt (1999), analyzing the dynamic relation and transmission of market prices among marketing channels in the beef sector, used a threshold error correction model accounting for the non-stationary nature of the prices and considered the asymmetric effects produced. From 1981 to early 1998, for weekly price data, they found significance for three different regimes, i.e. threshold behavior – existing mainly two regimes in the 1980's and dropping one of the regimes for a different one during the 1990's. Additionally, and in response to price shocks, lags were found in the adjustment period between each channel. Yet these lags during price adjustment – initially asymmetric, tended to decrease as the price shocks occurred in a later period in time, with the price adjustments becoming symmetric.

A subsequent study by Goodwin and Harper (2000) for the pork sector between 1987 and 1998, arrived at similar results. Earlier papers by Boyd and Brorsen (1988) - studying the pork sector with weekly data from 1974 to 1981, and Hanh (1990) - studying both the pork and beef sector, also found significant lags during the adjustment of price variations. Boyd and Brorsen (1988) found symmetric response to price changes supporting later findings mentioned above; yet Hanh (1990) found some asymmetric response to price changes within the different market channels.

Another result from Goodwin and Holt (1999) and Goodwin and Harper (2000) confirmed that price changes within market channels mainly propagated in one direction. i.e. response to price shocks were generally found to produce adjustments when these shocks were applied at the farm markets and from there the adjustments were passed on to the wholesale markets, and then to the retail markets. This finding corroborated earlier findings by Boyd and Brorsen (1985) and Schroeder (1988).

A paper by Bailey and Brorsen (1989) regarding three major cattle markets (i.e. feedlot operators and packers) in different states – Texas Panhandle, Nebraska, Colorado and one minor cattle market in Utah, found that there was asymmetric spatial adjustment for price variations. This was reflected in a difference in speed of adjustment for price changes – responding quicker to price increases than price decreases. They noted that price variation asymmetries may respond to asymmetries in adjustment costs between the feedlot operators and packers at each particular market.

Goodwin and Piggott (2001) studied market integration in spatially separate regional grain markets, through price linkages. They incorporated in their analysis thresholds that account for transaction costs, which delay price adjustments. The regional markets considered were for corn and soybean in North Carolina. Their results indicated that the markets are well integrated, and

also confirm the existence of thresholds points for price adjustments. Once these thresholds are accounted for in the model, the speed of adjustment for price variations is higher than when they are not considered. For a study conducting an extensive survey regarding asymmetric price transmission, see Meyer and von Cramon-Taubedel (2004).

Our empirical analysis uses an extended version of the Regime Switching Dynamics Correlation model (RSDC) of Pelletier (2006) by introducing state dependent i.e. time varying transition probabilities between the different states or regimes of correlation values. In this study, we consider the parsimonious model of dynamic correlations. An extension of the full unrestricted RSDC model is forthcoming in Tejeda et al. (2009). The transition probabilities serve to determine the impact of underlying related factors (prices and/or indexes) in the change of these dynamic correlations. That is, by the use of price ratio, returns and/or indexes as variables in these time varying transition probabilities, we are able to assess their impact on the switch between one state of dynamic correlation and another. These underlying related variables may either be weakly exogenous (i.e. lagged ratio or return series of our commodities analyzed) or exogenous factors, or a mix between them.

In this paper, we initially study two cases with different weakly exogenous variable. One case considers the ratio of soybeans to corn prices, and the other case considers the change (or return) in the ratio of soybeans to corn prices. This ratio is anticipated to remain stable during regular market periods and is anticipated to change as increased volatility impacts the market. The initial case where there is a constant transition probability for switching between regimes (i.e. only due to unaccounted exogenous factors), is a nested case within our model.

Our extended parsimonious RSDC model, i.e. state dependent, captures dynamic correlations and volatilities in our setting of corn, soybean, feeder cattle and livestock cattle prices, with less need of parameters being estimated than if using the Dynamic Conditional Correlation model of Engle (Engle 2002). This property and other advantages of the particular model, such as when combined with the ARMACH model of Taylor (1986) permits direct multi-step ahead conditional expectations, make it quite attractive.

Regarding the application of this model in our study of corn, soybean and cattle markets, it is able to depict the relations mentioned previously - corn and soybean markets sharing a certain geographical relation due to growing conditions in the U.S., and these crops sharing a relation with livestock cattle as feed for feeder cattle. This model permits the analysis of price transmission among these markets, and just as important the analysis of possible delays in the transmission of these price changes among markets – by identifying potential adjustment costs, considered threshold levels. In this sense, we find a threshold level or adjustment cost present in the relation between the crops and live cattle markets. There is no transmission of prices in these relations, and this adjustment cost may be a consequence of modifying the feed rations when corn and soybean increase prices. Also, the model's ability to determine the changing dynamic correlation among these markets is very relevant to gain efficiency in production operations.

Data:

We use weekly average of future prices for corn, soybean, feeder cattle and live cattle from the CBOT and CMEX respectively, obtained through CRB. These weekly average prices of futures are obtained by considering the nearest/closest maturity delivery date. Prices are from January

1998 till October 2008 - totaling 556 observations. We consider the difference of the log values of these prices. Three different scenarios are calculated to determine the effect of the spike in corn consumption due to ethanol mandated production. The first base scenario considers the entire data series previously mentioned, that is from January 1998 till October 2008. The next two scenarios considered are partitioned such that one series runs up till previous the energy act – that is from January 1998 to December 2004. And the other series considers from January 2004 till October 2008. These periods are taken in order to minimize potential different seasonality effects that may be present in one of the partitioned series, versus the other.

For the weakly exogenous variables being considered, besides the nested case of this being equal to zero, we calculate and present two different cases. One case considers a lagged period of the ratio of soybean to corn price. The other case considers the lagged change, or return, of the ratio of soybean to corn price. IN addition, we computed considering lagged values of these previous two weakly exogenous variables for two weeks, one month, three months, six months, one year; yet these did not present significant changes in results. i.e., each weakly exogenous variable for further lagged periods was statistically insignificant.

Summarizing, three different scenarios are calculated for the following *cases*:

i. the *nested case* (i.e. $x_{t-1} = 0$) for constant transition probability

ii. the *case with ratio of soybean to corn price* as weakly exogenous variable in the state dependent transition probability.

iii. the *case with changes (or returns) of ratio of soybean to corn price* as weakly exogenous variable in the state dependent transition probability.

First scenario considers time series for returns of weekly average futures prices between January 1998 and October 2008.

Second scenario considers time series for returns of weekly average futures prices between January 1998 and December 2004.

Third scenario considers time series for returns of weekly average futures prices between January 2004 and October 2008.

Econometric Model:

An extended version of the parsimonious or restricted Regime Switching Dynamic Correlations (RSDC) model will be used, from Pelletier (2006). The model considers dynamic correlations that change in value between different states or regimes, switching between these regimes according to a Markov chain. In other words, these correlations remain constant while the process is in a certain regime and when there is a switch to a different regime, the correlations change value. A Markov chain with transition probabilities governs the switching process between regimes.

The initial case of different correlation values for each regime corresponds to the case of constant transition probabilities operating in the regime switching model. That is, only unknown exogenous factors account for the change from one correlation value to another. These

correlation values and their dynamics serve as the base scenario for our analysis. By incorporating specific related underlying economic variables in the transition probabilities for switching from one correlation to another, we are able to assess a two-fold impact they may have by calculating: (i.) the new correlation levels that may exist between these markets, and (ii.) the new dynamics that these correlation levels may present when switching from one regime to another, once these underlying related variables are accounted for in the dynamic process.

The model can be described as follows, by considering a K - multivariate time process:

$Y_t = H_t^{1/2} U_t$ with $U_t \sim i.i.d.(0, I_K)$ - where Y_t corresponds to our time series, a filtered process.

The dynamic covariance matrix H_t, is decomposed into standard deviations and correlations:

$H_t \equiv S_t \Gamma_t S_t$ where S_t is a *Diagonal matrix* with *standard deviations*: $s_{k,t}$ $k = 1 \ldots\ldots K$

Γ_t is the *correlations matrix*

The time-varying standard deviations are modeled directly by using the ARMACH process, as per Taylor (1986). In this way, there is no need to model the variances through GARCH and then use a non-linear square root to obtain the standard deviation - which poses a limitation for directly calculating subsequent multiple steps forward conditional expectations. Pelletier (2006).

In ARMACH, the conditional standard deviation follows:

$s_t = \omega + \sum_{i=1}^{q} \tilde{\alpha}_i \, |y_{t-i}| + \sum_{j=1}^{p} \beta_j \, s_{t-j}$ with $\tilde{\alpha}_i = \alpha_i / E|\tilde{u}_t|$ for stationary purposes.

This provides ease of use for computation of conditional expectations, since it enters as a linear operator

The correlation matrix Γ_t used will be that of the restricted or parsimonious model, i.e.

$$\Gamma_t = \Gamma\lambda(\Delta_t) + I_K\big(1 - \lambda(\Delta_t)\big)$$

where:

Γ is a *fixed* KxK correlation matrix, such that Γ_t has values corresponding to a certain state or regime according to the transition probability being considered. That is, values of Γ_t for each regime depend on the transition probability between regimes. And these probabilities may be different depending if they are considered constant transition probability, or a time-varying transition probability with underlying related variables being taken into account, as noted below. I_K is a KxK identity matrix (K: # of regimes).

$\lambda(\Delta_t)\ \epsilon\ [0,1]$ (provides assurance of eliminating possibilities of non-PSD correlation matrix) is a univariate random process governed by a Markov chain process Δ_t that takes N possible values for regimes ($\Delta_t = 1,2, \dots \dots \dots \dots N$), and is independent of U_t.

The 'probability law' governing Δ_t is defined by its transition probability matrix: Π_t which can be a function of either weakly exogenous or exogenous variables (x_{t-1}). The weakly exogenous variables considered in this study are i.- the lagged ratio of futures soybeans to corn price, and ii.- the change or return of the ratio of soybean to corn prices – as we assess these prices and their variability (particularly corn) on the dynamic relation between these crops and cattle prices. We consider one lagged period and also lagged periods of prices for two weeks, one, three, six, and 12 months. Though here we only present results for one lagged period (week), since further lagged periods were not statistically significant. Appendix 4 includes charts of these two (i. and ii.) weakly exogenous variables.

The probability governing the Markov chain has the following logistic form as per Diebold et al. (1994); which considers the transition into either one of two regimes at time t (Δ_t=1 or Δ_t= 2), being that it was at regime 1 at the previous period $t-1$, i.e. (Δ_{t-1}= 1):

$$P(\Delta_t = 1\ or\ \Delta_t = 2 \mid \Delta_{t-1} = 1\ ,\ x_{t-1}; \beta_1) = \frac{\exp(x'_{t-1}\beta_1)}{1+\exp(x'_{t-1}\beta_1)} \quad or \quad 1 - \frac{\exp(x'_{t-1}\beta_1)}{1+\exp(x'_{t-1}\beta_1)} \qquad (1)$$

As mentioned before, the original model considered constant probabilities for the transition between one correlation regime and another – that is, having unaccounted exogenous factors generate the switching process from one period to the next. Our extended model incorporates state dependent – time varying transition probabilities. Hence the initial model is nested within our model. State dependent probabilities were calculated by incorporating individual one lagged period - and subsequently further lagged periods, of series and indices in the previous logistic setting. These series represent underlying related variables to the dynamic process.

The coefficients β_1 in the conditional transition probabilities are b_{11} and b_{12} for the constant and the weakly exogenous variable, respectively - at *Regime **1***. Similarly, the coefficients β_2 in the probabilities are b_{21} and b_{22} for the constant and weakly exogenous variable, respectively – at *Regime **2***. The nested case of constant transition probabilities considers b_{12} = 0 and b_{22} = 0.

The case of our two regimes dynamic correlations model may be estimated as the product of each correlation level at a certain regime - either Γ for regime 1 or $\Gamma * \lambda$ for regime 2, and the probability of being at that specific regime [1]:

$$\Gamma_t = \Gamma * P(\Delta_t = 1 \mid x_{t-1}; \theta) + \Gamma * \lambda * P(\Delta_t = 2 \mid x_{t-1}; \theta)$$

To assess the impact of a significant coefficient of a weakly exogenous variable i.e. what we consider a certain threshold level, we do a first order Taylor approximation for the conditional probability at (1) for a small value around our weakly exogenous variable x_{t-1} valued at zero.

[1] Here $P(\Delta_t = 1 \mid x_{t-1}; \theta) = P(\Delta_t = 1, \Delta_t = 1 \mid x_{t-1}; \theta) + P(\Delta_t = 1, \Delta_t = 2 \mid x_{t-1}; \theta)$ - further details in Diebold et al. (1994).

For example - being previously at $\Delta_{t-1}= 1$, then at $\Delta_t= 1$; and for a small value of x_{t-1} around zero:

$P(\Delta_t= 1 \mid \Delta_{t-1}= 1 , x_{t-1}; \beta_1) =$

$$= P(\Delta_t= 1 \mid \Delta_{t-1}= 1 , x_{t-1}; \beta_1)|x_{t-1} = 0 + \frac{\partial P(\%)}{\partial x}|x_{t-1} = 0 *(x_{t-1} - 0)$$

Hence

$P(\Delta_t= 1 \mid \Delta_{t-1}= 1 , x_{t-1}; \beta_1) =$

$$= P(\Delta_t= 1 \mid \Delta_{t-1}= 1 ; \beta_1) + \boldsymbol{b}_{12} \frac{\exp(x'_{t-1}\beta_0)}{[1+\exp(x'_{t-1}\beta_0)]^2} |x_{t-1} = 0 * x_{t-1}$$

Which results in:

$$P(\Delta_t= 1 \mid \Delta_{t-1}= 1 , x_{t-1}; \beta_1) - P(\Delta_t= 1 \mid \Delta_{t-1}= 1 ; \beta_1) = \boldsymbol{b}_{12} \frac{\exp(\mathrm{b}_{11})}{[1+\exp(\mathrm{b}_{11})]^2} * x_{t-1}$$

Or

$$\Delta P(\Delta_t= 1 \mid \Delta_{t-1}= 1 , \boldsymbol{x_{t-1}}; \beta_1) = \boldsymbol{b}_{12} \frac{\exp(\mathrm{b}_{11})}{[1+\exp(\mathrm{b}_{11})]^2} * \boldsymbol{x_{t-1}}$$

That is, a small change in the probability of remaining in regime 1 (spillover effect), resulting from a small change in the weakly exogenous variable $\boldsymbol{x_{t-1}}$**,** is proportional to the product of the coefficient $(\boldsymbol{b_{12}})$ of the weakly exogenous variable and the small change of this variable. If this coefficient $\boldsymbol{b_{12}}$ is insignificant, then the weakly exogenous variable would not form a threshold level for price transmission among markets. i.e. changes in this weakly exogenous variable would not produce variations in the evolution of our correlation values, and thus these market correlations would evolve completely exogenously. If this coefficient is positive, then positive variations of our weakly exogenous variable $(\boldsymbol{x_{t-1}})$ will lead to a higher probability of being at regime 1 (i.e. spillover effect), versus switching to a different correlation regime if this coefficient $(\boldsymbol{b_{12}})$ was zero or non-significant. Conversely, if this coefficient is negative, then positive variations of our weakly exogenous variable would lead to a larger probability of changing to a different correlation level and thus reducing any spillovers of the dynamic process.

Results:

We present the results for the correlations among the markets for the different cases in each scenario described at the end of the Data section, leaving out the conditional volatilities for a later analysis. For each different time period scenario, model selection preference may be assessed using either the BIC or the Rivers-Vuong test criteria. The BIC test applies in the case of constant transition probabilities versus that of state dependent probabilities, since nested models. The Rivers-Vuong test serves to compare between the two state dependent transition probabilities, as they are non-nested models.

Table 1 below is for the three cases of transition probabilities in the first scenario, i.e. from January 1998 to October 2008.

Results show insignificant differences between the correlation levels among the commodity prices for both regimes, in all three cases. i.e. similar correlation levels when considering constant transition probabilities for regime switching versus the cases of state dependent transition probabilities.

Table 1.

Betas Estimated January 1998 - October 2008

		Constant Transition Probability (Beta for X = Zero)	Standard Errors		*State Dependent Probability Ratio Sybn/Corn*	Standard Errors		*State Dependent Probability Returns Sybn/Corn*	Standard Errors	
	Likelihood	-4810.4			*-4809.1*			*-4806.0*		
Γ	**Correlations Regime 1**									
	Corn -Soybean	0.74636	0.0405	•	0.75019	0.0347	•	0.73091	0.0342	•
	Corn -Feeder Cattle	-0.20966	0.0607	•	-0.20733	0.0597	•	-0.20170	0.0596	•
	Corn - Live Cattle	0.03800	0.0550		0.04139	0.0559		0.02611	0.0535	
	Soybean - Feeder Cattle	-0.10933	0.0623		-0.10816	0.0615		-0.09870	0.0603	
	Soybean - Live Cattle	0.06058	0.0635		0.06578	0.0629		0.04544	0.0589	
	Feeder Cattle -Live Cttle	0.81682	0.0268	•	0.82095	0.0248	•	0.80459	0.0290	•
λ	***Lambda Transtn***	0.3467	0.0540	•	0.3496	0.0553	•	0.3135	0.0543	•
$\Gamma * \lambda$	**Correlations Regime 2**									
	Corn -Soybean	0.25880	0.0427	•	0.26230	0.0432	•	0.22916	0.0411	•
	Corn -Feeder Cattle	-0.07270	0.0239	•	-0.07249	0.0238	•	-0.06324	0.0217	•
	Corn - Live Cattle	0.01318	0.0192		0.01447	0.0197		0.00819	0.0168	
	Soybean - Feeder Cattle	-0.03791	0.0224		-0.03782	0.0223		-0.03094	0.0197	
	Soybean - Live Cattle	0.02101	0.0222		0.02300	0.0223		0.01425	0.0186	
	Feeder Cattle -Live Cttle	0.28323	0.0451	•	0.28704	0.0462	•	0.25226	0.0447	•
β										
	problty beta - b11	0.08911	0.1149		-1.8308	3.5832		0.3470	0.5251	
	problty beta - b21	-0.47852	0.2091	•	-5.7106	4.8438		-0.7242	0.8667	
	problty beta - b12	0			0.7581	1.4113		-0.2712	0.1006	•
	problty beta - b22	0			2.0437	1.7366		0.0358	0.1170	

Standard errors for correlations at Regime 2, for all three scenarios are calculated by delta method.

More relevant is that the dynamic correlations between corn and soybeans are significant and positive as anticipated, since these share common production conditions. Also a positive and significant value is obtained for the correlations between feeder cattle and live cattle (fed cattle) as expected, since these two markets are directly related in the marketing chain.

An inverse (negative) significant correlation value is determined between corn and feeder cattle prices as anticipated by the literature, from the effect of the increase in the corn price as it is a main component of the feed ration. Also, an interesting finding is that there is no significant correlation between corn or soybean prices with live cattle prices. This reveals a threshold of adjustment cost, as higher feed prices are not passed on to the live cattle prices. This may be a direct consequence of modifying feeding rations when faced by increased corn prices, also anticipated by the literature.

Another point to be addressed is that one coefficient of our weakly exogenous variable used in the state dependent transition probability – returns of soybean/corn price ratios, is statistically significant. That is, the weakly exogenous variable has an impact in the conditional probability of being at regime one and staying there or switching to the other correlation regime. The resulting coefficient (b_{12}) is negative, which indicates a decreased (increased) probability of switching to regime number two in the following period, once being in regime number one in the previous period, for a negative (positive) change in the ratio of soybean to corn price. In other words, for negative returns of the ratio (i.e. for increases in corn price with respect to soybean price), there is a larger probability of staying at the higher correlation level, in regime 1. This reveals a potential spillover effect driven by the difference from the increase in the corn price versus the soybeans price, for each subsequent period. Yet it is not clear how to interpret that the effect is being produced through a return or change in the price ratio, and not through the role of the price ratio in itself. For this latter case we find no statistically significant coefficients. A proper assessment of the spillover impact of variations of the significant coefficients can be obtained through the first order Taylor approximation results at the top of page 15. Charts of the dynamic correlations between these markets are in Appendix 5.

Table 2 below presents the results for the second scenario, i.e. from January 1998 to December 2004, which is before the ethanol driven corn consumption. Again positive and significant correlation values are determined for both corn and soybean, and feeder and fed cattle prices. Furthermore, the level values in both regimes are similar to the ones from the previous scenario.

However, in this time period scenario, there is no statistical inverse or negative relation between corn and feeder calf prices, as the previous scenario. This is interesting point may be anticipated, as there was not a substantial increase in corn price during this pre ethanol driven corn consumption period, and hence the corn price had no effect on feeder prices.

Also, again the state dependent transition probability which considers the changes or returns of the soybean to corn price ratio, has a significant inverse or negative coefficient in b_{12}. Same as before, this indicates an increase in staying at regime 1 for a negative change in the ratio of soybean to corn price, or when corn is increasing its' price with respect to soybean. As mentioned previously, the interpretation of this spillover effect being driven by price ratio changes is not as straightforward as if it was driven by the price ratio itself. Dynamic correlations for these markets are in Appendix 6.

Table 2.

	Betas Estimated January 1998 - December 2004									
		Constant Transition Probability (Beta for X = Zero)	Standard Errors		*State Dependent Probability Ratio Sybn/Corn*	Standard Errors		*State Dependent Probability Returns Sybn/Corn*	Standard Errors	
	Likelihood	-3109.8			*-3103.6*			*-3100.1*		
Γ	**Correlations Regime 1**									
	Corn -Soybean	0.72448	0.0487	*	0.73072	0.0415	*	0.69819	0.0415	*
	Corn -Feeder Cattle	-0.07767	0.0708		-0.08534	0.0712		-0.06178	0.0711	
	Corn - Live Cattle	0.11484	0.0628		0.11874	0.0656		0.10427	0.0603	
	Soybean - Feeder Cattle	-0.04863	0.0776		-0.05637	0.0802		-0.03699	0.0763	
	Soybean - Live Cattle	0.10503	0.0812		0.11679	0.0831		0.08541	0.0739	
	Feeder Cattle -Live Cttle	0.83971	0.0291	*	0.84608	0.0291	*	0.82359	0.0329	*
λ	***Lambda Transtn***	0.3241	0.0663	*	0.3339	0.0695	*	0.2561	0.0653	*
$\Gamma * \lambda$	**Correlations Regime 2**									
	Corn -Soybean	0.23480	0.0506	*	0.24397	0.0526	*	0.17884	0.0468	*
	Corn -Feeder Cattle	-0.02517	0.0235		-0.02849	0.0245		-0.01583	0.0187	
	Corn - Live Cattle	0.03722	0.0217		0.03964	0.0234		0.02671	0.0169	
	Soybean - Feeder Cattle	-0.01576	0.0254		-0.01882	0.0271		-0.00948	0.0197	
	Soybean - Live Cattle	0.03404	0.0272		0.03899	0.0289		0.02188	0.0197	
	Feeder Cattle -Live Cttle	0.27215	0.0565	*	0.28248	0.0596	*	0.21096	0.0544	*
β	problty beta - b11	0.28354	0.0872	*	1.1430	2.4407		0.6835	0.3545	
	problty beta - b21	-0.138566	0.1654		-5.6979	4.5461		-0.5137	0.6877	
	problty beta - b12	0			-0.3886	1.0313		-0.4245	0.1358	*
	problty beta - b22	0			2.1946	1.5915		0.0480	0.1722	

Finally, Table 3 below considers the last scenario which specifically includes the effect of the ethanol driven corn consumption. We obtain similar results in the positive correlations for corn and soybean and feeder and live cattle prices, as previous scenarios. Here there is also an inverse (negative) correlation for corn and feeder prices for the first case of constant transition probabilities, and the last case considering state dependent probabilities with the change in soybean to corn price ratio. The middle case, considering the ratio of prices as weakly exogenous variable, is significant but at a lower 10% level.

These inverse or negative correlations are more significant in case of regime 1, i.e. at the higher negative correlation level, and less significant (at 10% level) for correlations at regime 2. The inverse relation between corn and feeder cattle is anticipated for cases of increasing corn prices, according to the literature. This increased corn price stemming from the ethanol driven corn consumption. This can be further seen in the chart at the top of Appendix 4, with the decreasing

Soybean to Corn price ratio, beginning from the end of 2005 and into 2006 and later the ratio drops below 2.

Table 3.

	Betas Estimated January 2004 - October 2008									
		Constant Transition Probability (Beta for X = Zero)	Standard Errors		*State Dependent Probability Ratio Sybn/Corn*	Standard Errors		*State Dependent Probability Returns Sybn/Corn*	Standard Errors	
	Likelihood	*-2221.7*			*-2218.1*			*-2213.7*		
Γ	**Correlations Regime 1**									
	Corn -Soybean	0.75635	0.0926	•	0.80012	0.0471	•	0.81676	0.0345	•
	Corn -Feeder Cattle	-0.40170	0.1576	•	-0.31476	0.1723		-0.20902	0.0994	•
	Corn - Live Cattle	-0.07805	0.1298		-0.04485	0.1186		-0.04123	0.0979	
	Soybean - Feeder Cattle	-0.15149	0.1288		-0.13939	0.1328		-0.06960	0.0912	
	Soybean - Live Cattle	0.03122	0.1362		0.00103	0.1086		-0.00468	0.0886	
	Feeder Cattle -Live Cttle	0.80423	0.0456	•	0.72087	0.0664	•	0.63690	0.0653	•
λ	***Lambda Transtn***	0.2702	0.1030	•	0.3308	0.1011	•	0.2726	0.1048	•
$\Gamma * \lambda$	**Correlations Regime 2**									
	Corn -Soybean	0.20434	0.0818	•	0.26464	0.0823	•	0.22266	0.0861	•
	Corn -Feeder Cattle	-0.10853	0.0594		-0.10411	0.0653		-0.05698	0.0348	
	Corn - Live Cattle	-0.02109	0.0360		-0.01483	0.0395		-0.01124	0.0270	
	Soybean - Feeder Cattle	-0.04093	0.0381		-0.04610	0.0461		-0.01897	0.0259	
	Soybean - Live Cattle	0.00844	0.0369		0.00034	0.0359		-0.00128	0.0242	
	Feeder Cattle -Live Cttle	0.21728	0.0837	•	0.23843	0.0761	•	0.17363	0.0691	•
β										
	problty beta - b11	0.3829	0.1712	•	-16.6206	13.7475		8.7214	4.4043	
	problty beta - b21	-0.1974	0.2233		-14.7215	10.0174		1.5026	0.2152	•
	problty beta - b12	0			7.1297	5.4156		-2.2910	1.2495	•
	problty beta - b22	0			5.92734	3.7339		0.05498	0.0492	

In addition, once again there is a statistically significant inverse (negative) relation for our case of state dependent transition probability, considering the change (or returns) in the soybean to corn price ratio (b_{12}). Though this significance is at a lower 10% level, this coefficient is much larger than the coefficient obtained for the previous scenario.

In other words, during this time period there is a higher role in the probability of remaining in the higher correlation regime 1, producing a spillover effect, for the case of a negative return in the price ratio. That is, this time period contains negative changes in the price ratio stemming from increased corn prices with respect to soybeans price, resulting in a larger coefficient that has a

bigger role in spillover effects. Charts of the dynamic correlations are in Appendix 7, where we can see the differences between the first cases with constant transition probabilities versus the cases that have state dependent probabilities. In these latter dynamic correlations, spillover effects are noted.

We revisit both charts of the weakly exogenous variables considered, i.e. ratio of soybean to corn futures prices, and the change (or return) in this price ratio from Appendix 4 for the scenarios of time considered. In the first chart we can see that up to the end of 2004 - besides mid 2004 having a large spike and drop in the ratio, the rest of periods between December and February are relatively stable around 2.2 to 2.4, where crop producers are deciding which crop to plant and produce. However, at the end of 2005 and beginning of 2006 season - this ratio begins to drops quite below 2, as it anticipates increases in corn consumption from the ethanol production.

This ratio continues to steadily decrease (i.e. continuously generating negative changes in the ratio) till the end of 2007, producing fewer switches in the dynamic correlation levels of the markets, than for the previous scenarios considered. In addition, these prolonged periods of staying at certain regimes are for values of higher correlation. In other words, the markets stay at higher positive or negative correlation levels once these negative returns or changes in the price ratio are considered.

After 2007, the ratio steadily begins rising as crop producers are facing record prices (Appendix 1) and record production for corn. This steady rise in the ratio of prices, for an increasing price of soybeans with respect to corn is producing steady positive returns or changes of the ratio. This in turn is producing a longer (or prolonged) period of time of lower correlation values between the markets, than for previous scenarios being considered.

As mentioned previously, a proper assessment of the spillover impact from variations of the significant coefficient can be obtained through the first order Taylor approximation results at the top of page 15. Simple calculations reveal that a 10% change in the weakly exogenous variable (return of soybean to corn price ratio), produces a change in the probability for regime switching of less than 0.04% during this time period. We contrast this probability change with that of the previous period, i.e. from January 1998 to December 2004 or the second scenario. In this case, a 10% change in the weakly exogenous variable produces a change in the probability for regime switching of about 9.5%. In other words, there is much higher probability of changing between the regimes, and hence changing correlation values, during the period previous to the ethanol driven corn consumption than in the latter period. Hence, there is much less possibility of spillover effects in the second scenario than in the third scenario. Conversely, the spillover effects captured in our last time period are quite stable and not obtained in the previous time period, nor obtained in the current period when using constant transition probabilities. These identified spillover effects may be considered for policy analysis or efficiency gains in operations of these markets.

Conclusion

The effects of the recent increase in corn and soybean prices, and their volatilities, on related cattle markets is studied by using a multivariate time series model. We specifically determine the dynamic correlations between corn, soybean and feeder cattle and live cattle markets by extending a parsimonious regime switching dynamic correlations model. The model extension introduces underlying related variables that may have a role in the evolution of the correlation process. We consider two partitioned scenarios or time periods, where one of them is previous to the mandated ethanol production and the other is after this policy. Additionally, we first consider the scenario depicting both previous time periods together, i.e. as the initial complete time series.

Correlation levels between markets such as corn and soybeans and feeder cattle and live cattle are positive and consistent with the literature for all time periods considered. We also find that there is not a negative correlation between corn prices and feeder cattle for the period previous to the mandated ethanol production, yet there is negative or inverse correlation for the other two time periods considered. This negative relation is consistent with the literature where increases in corn price result in declining feeder prices, i.e. results are as anticipated since the sharp increase in corn prices is produced in the series post mandated ethanol production.

In the case of the underlying variables, we find that there is a significant effect of the changing soybeans to corn price ratio on the dynamic relationships/correlations between the previous markets, especially for the last scenario considered, i.e. between 2004 and 2008, compared to the scenarios of the previous years. The first scenario of the entire series may have this latter effect mitigated, due to the longer period considered. A plausible cause for this effect – post end of 2005, may be due to the increased corn consumption for ethanol production, since crop producers were anticipating increase in demand, and producers of ethanol were securing purchases during the year. In addition, spillover effects are veiled when considering this related variable in comparison to the case of constant probabilities between regimes. However, as mentioned previously, it is not clear what the interpretation of this changing or return in price ratio may be, since the price ratio in itself is an indicator of profitability for producers as mentioned earlier.

Further analysis may require additional series to be considered as weakly exogenous variables such as ratio-to-stocks use, exchange rates, and contract volumes among others.

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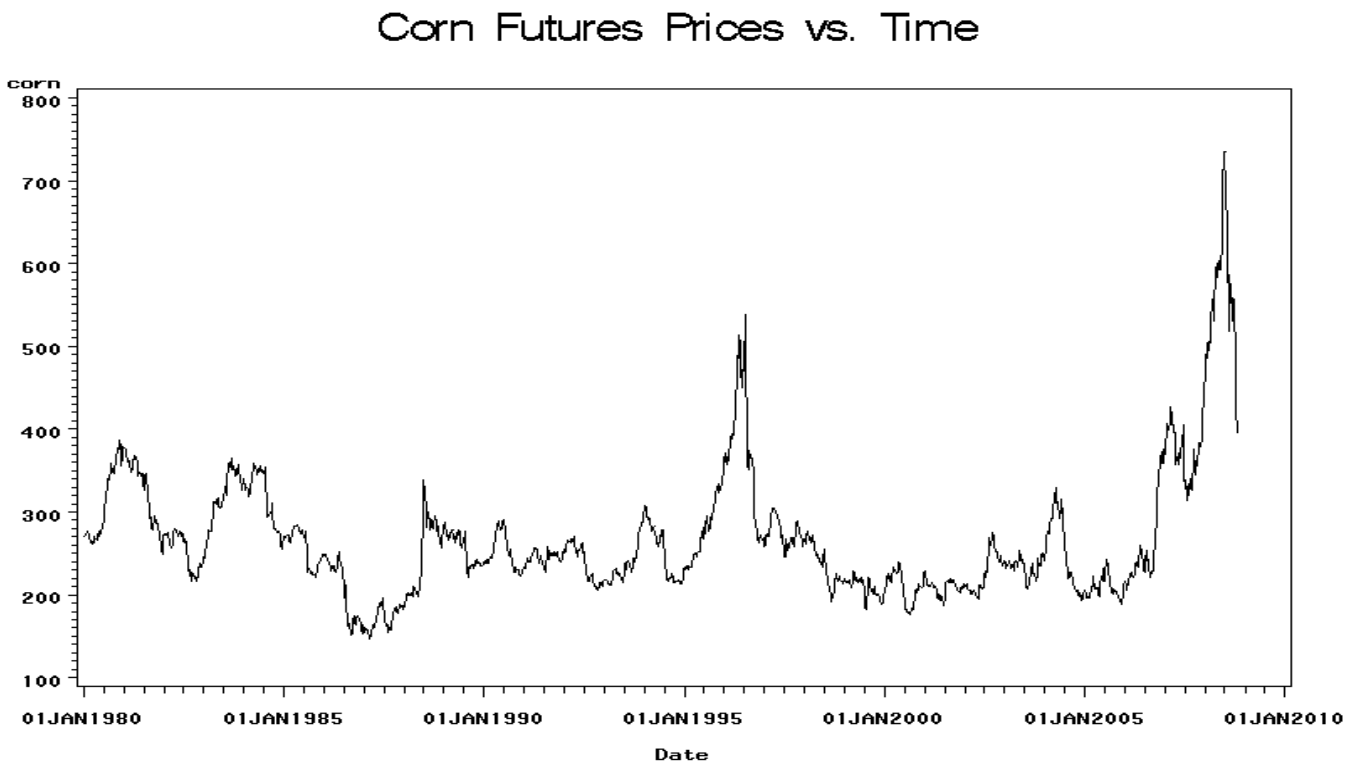
Appendix 1


Corn Futures Prices vs. Time
corn
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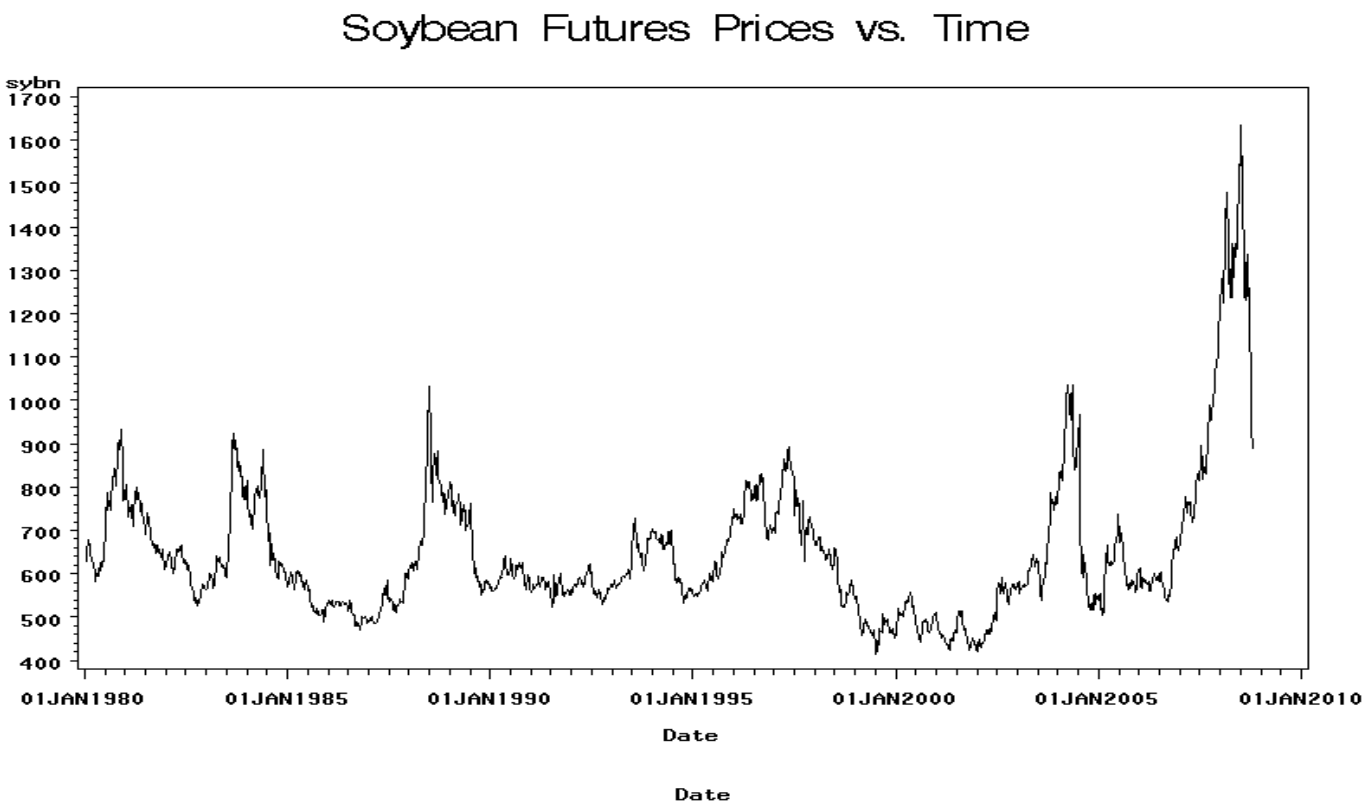
700
600
500
400
300
200
100
01JAN1980
01JAN1985
01JAN1990
01JAN1995
01JAN2000
01JAN2005
01JAN2010
Date


Soybean Futures Prices vs. Time
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1500
1400
1300
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1100
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900
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700
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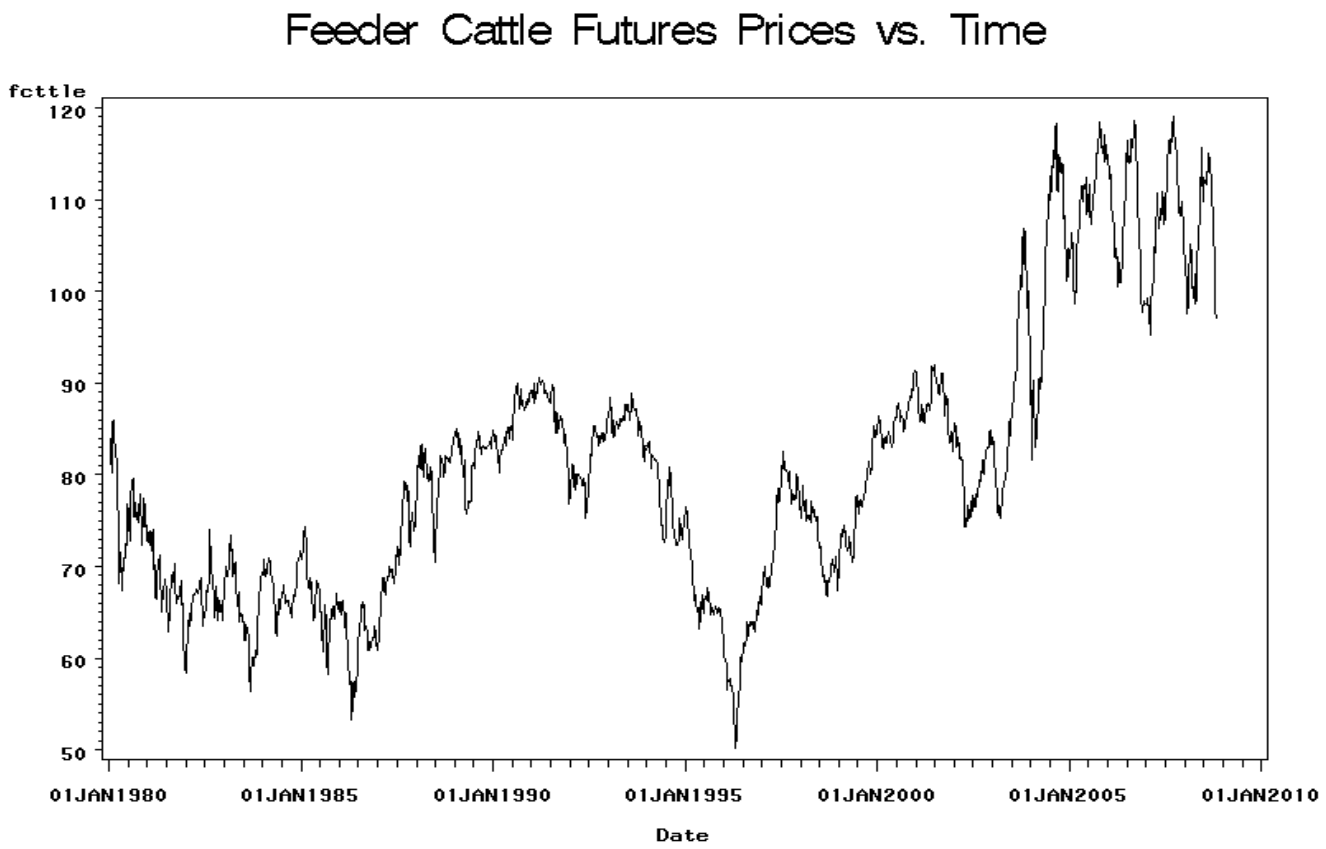
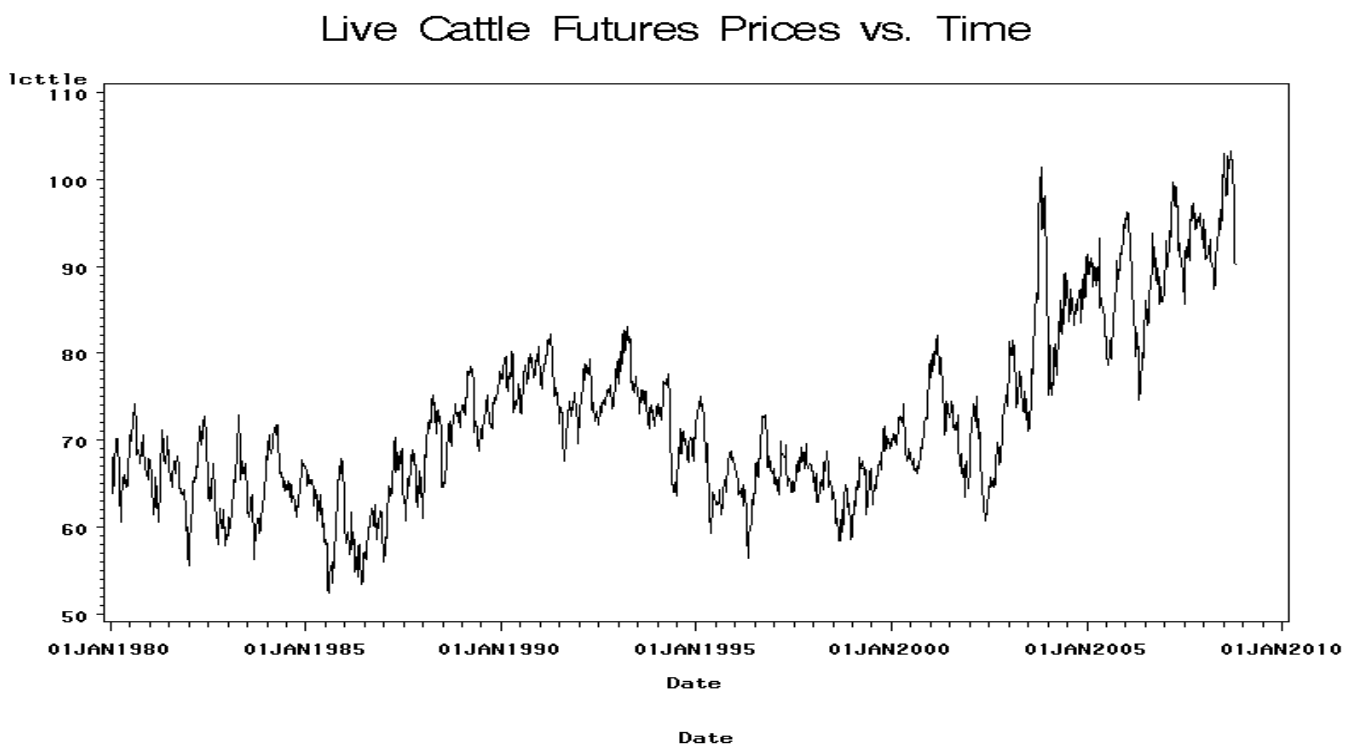
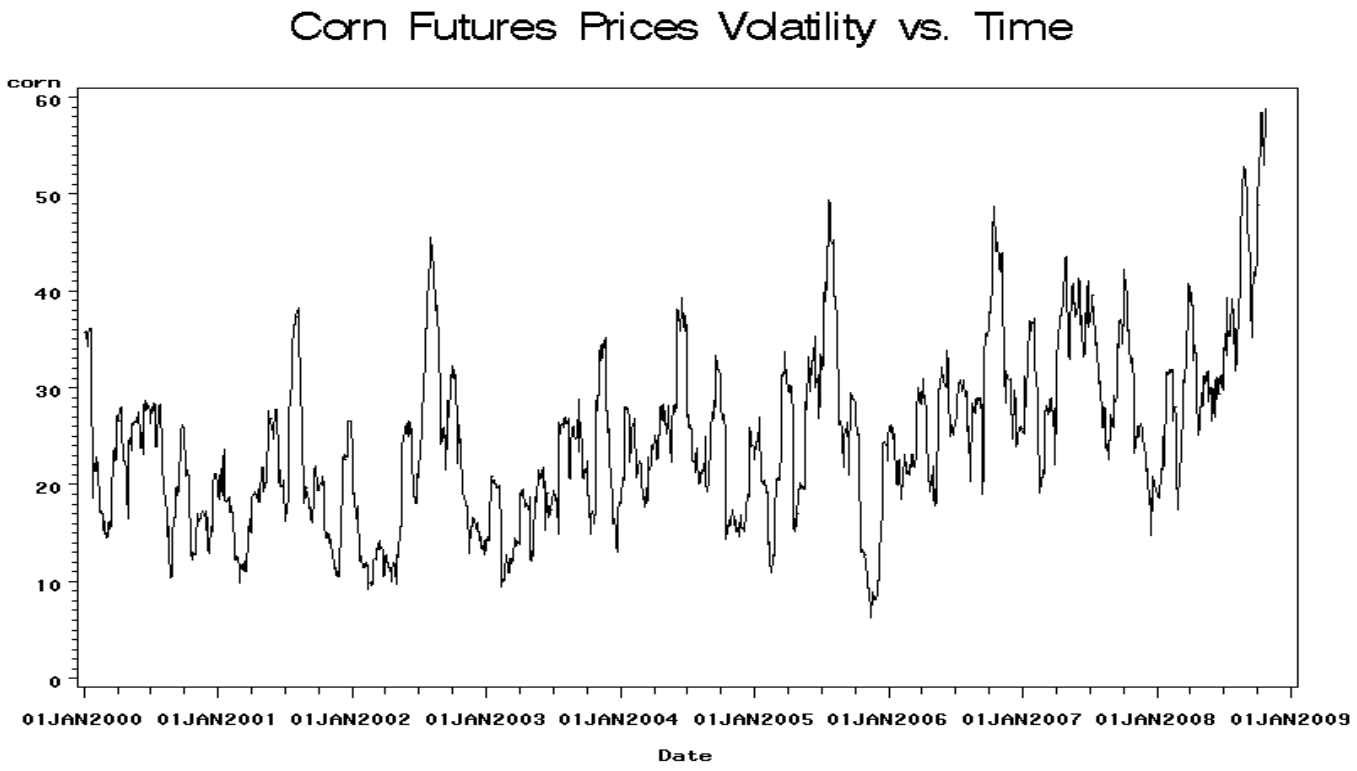
400
01JAN1980
01JAN1985
01JAN1990
01JAN1995
01JAN2000
01JAN2005
01JAN2010
Date
Date

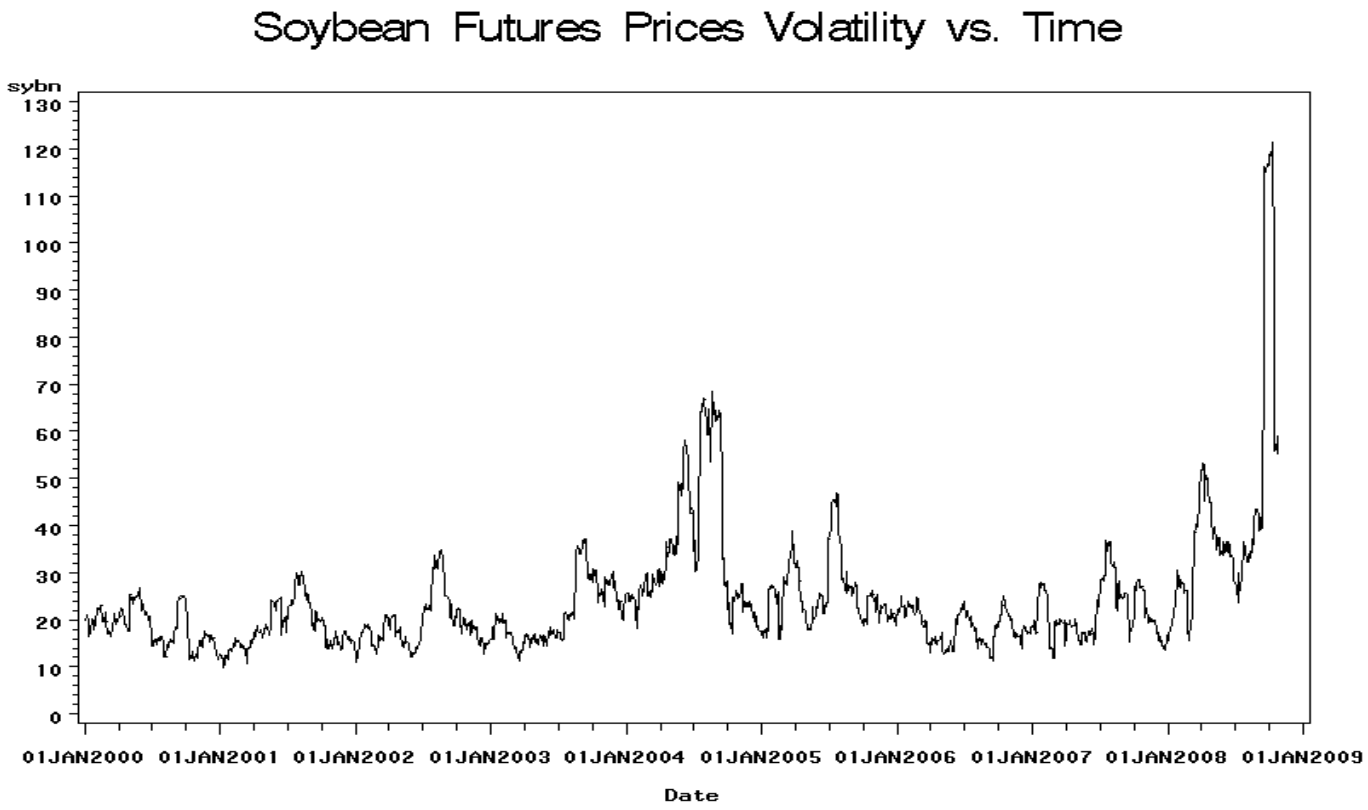
Appendix 1


Feeder Cattle Futures Prices vs. Time
fcttle
120
110
100
90
80
70
60
50
01JAN1980
01JAN1985
01JAN1990
01JAN1995
01JAN2000
01JAN2005
01JAN2010
Date


Live Cattle Futures Prices vs. Time
lcttle
110
100
90
80
70
60
50
01JAN1980
01JAN1985
01JAN1990
01JAN1995
01JAN2000
01JAN2005
01JAN2010
Date
Date

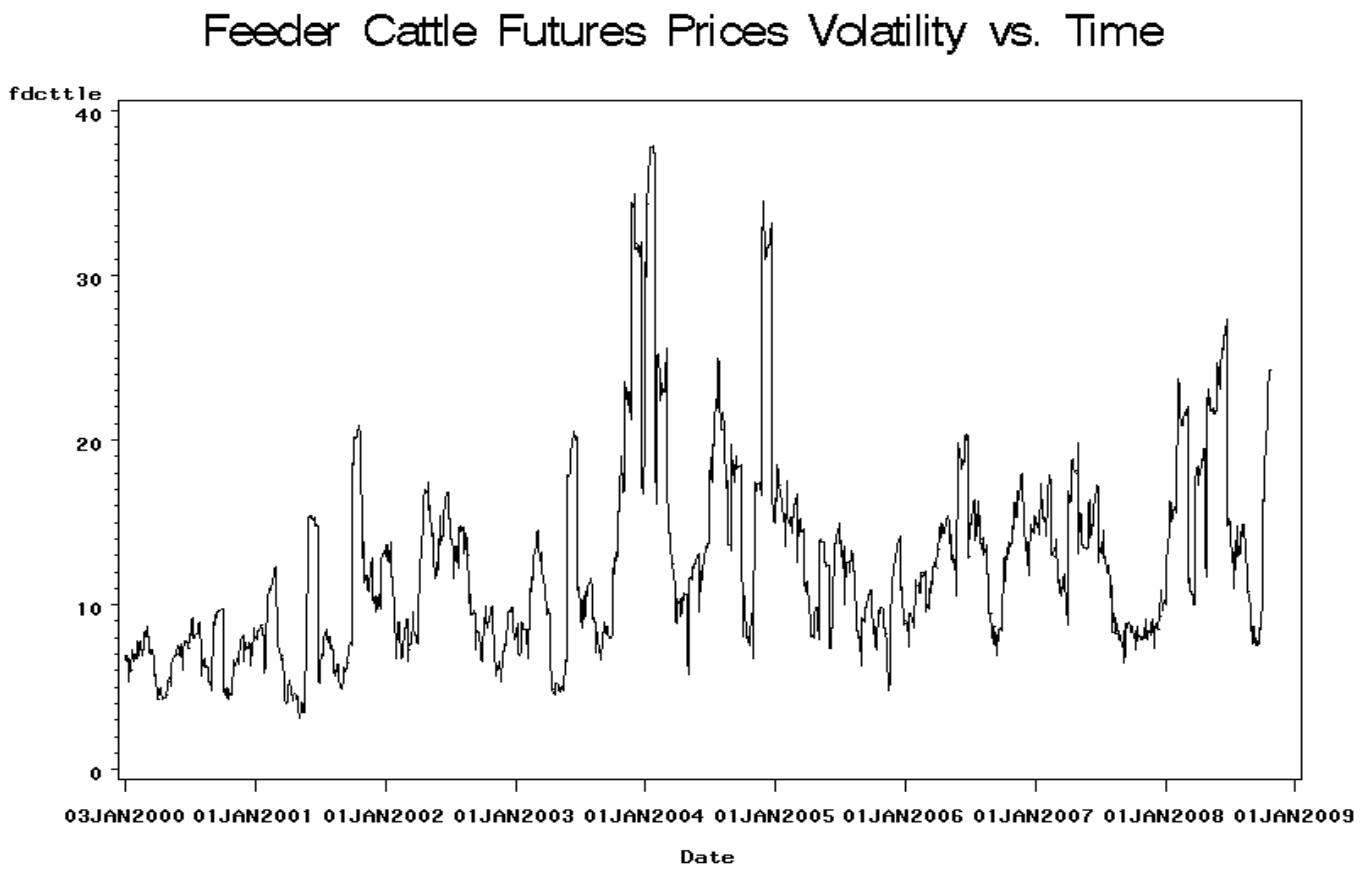
Appendix 2

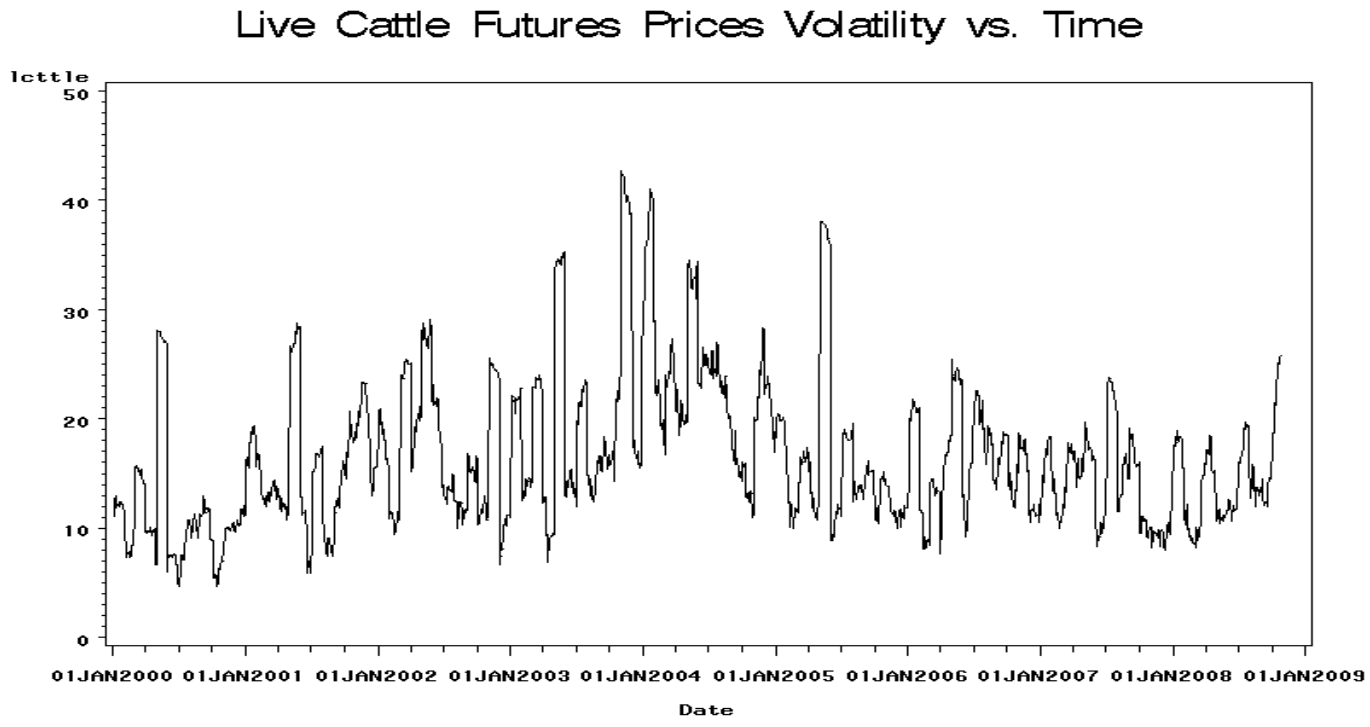




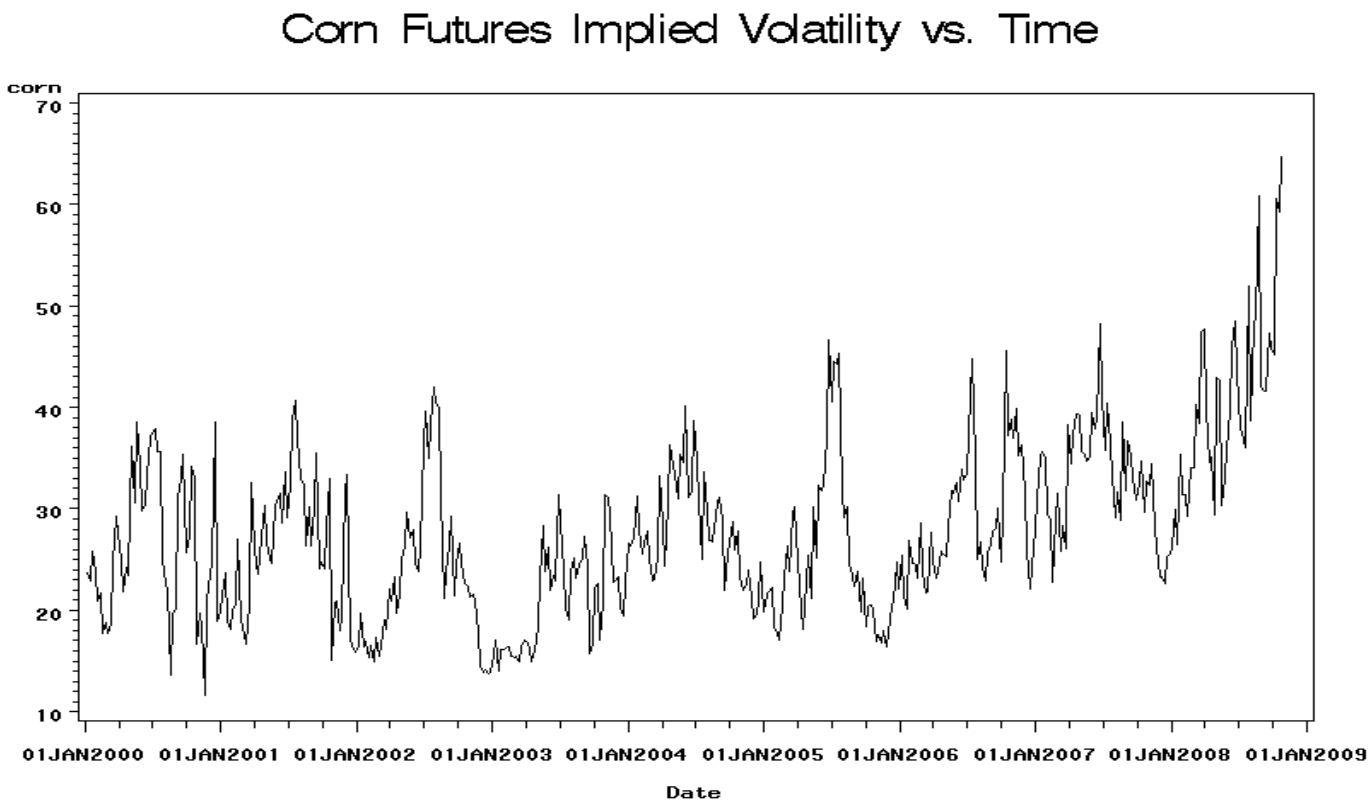
Friday Sep 12/08 Soybean Volatility spike due to last day of trade of September contracts, with many 'shorts' having to deliver yet facing a smaller harvest supply due to delay in year planting. Price spiked a record 2.74 $/bu. i.e. a case of 'short' squeeze

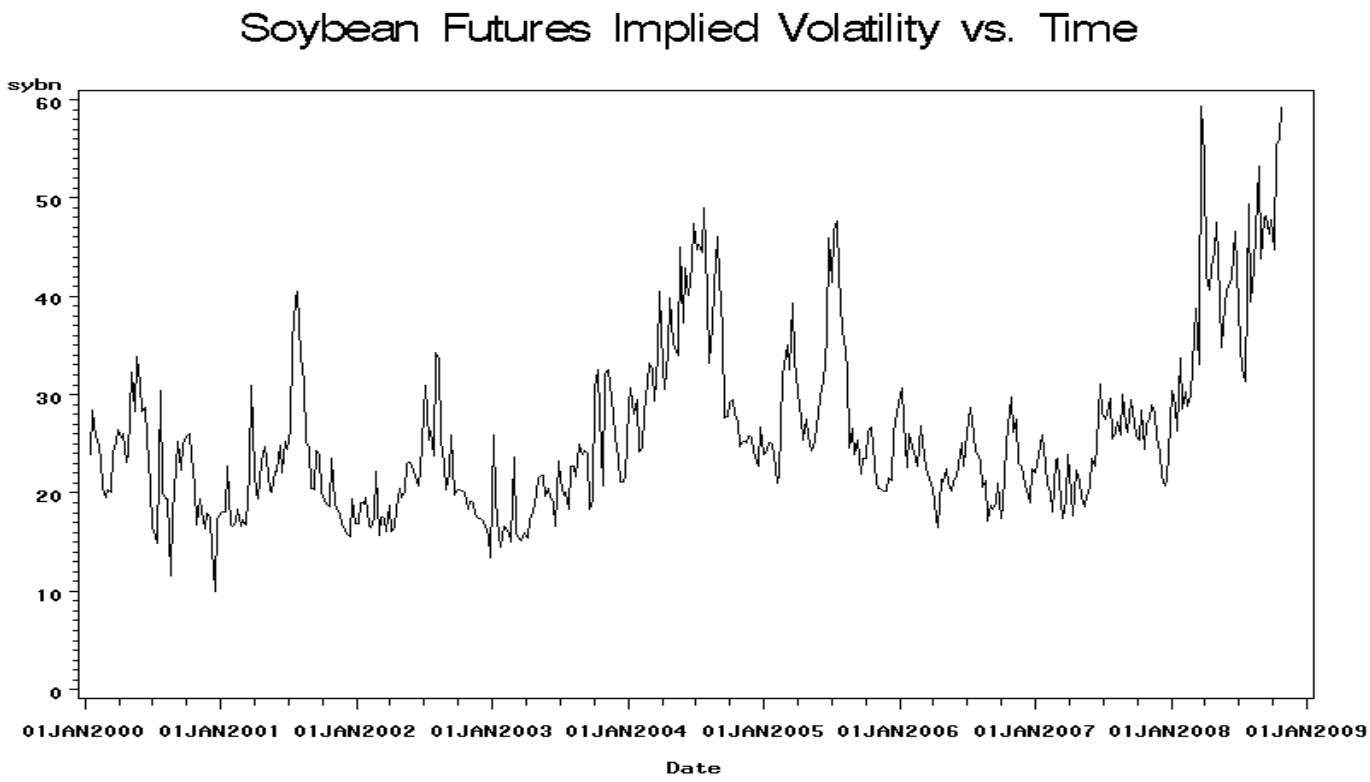
Appendix 2


Feeder Cattle Futures Prices Volatility vs. Time
fdcttle
40
30
20
10
0
03JAN2000 01JAN2001 01JAN2002 01JAN2003 01JAN2004 01JAN2005 01JAN2006 01JAN2007 01JAN2008 01JAN2009
Date

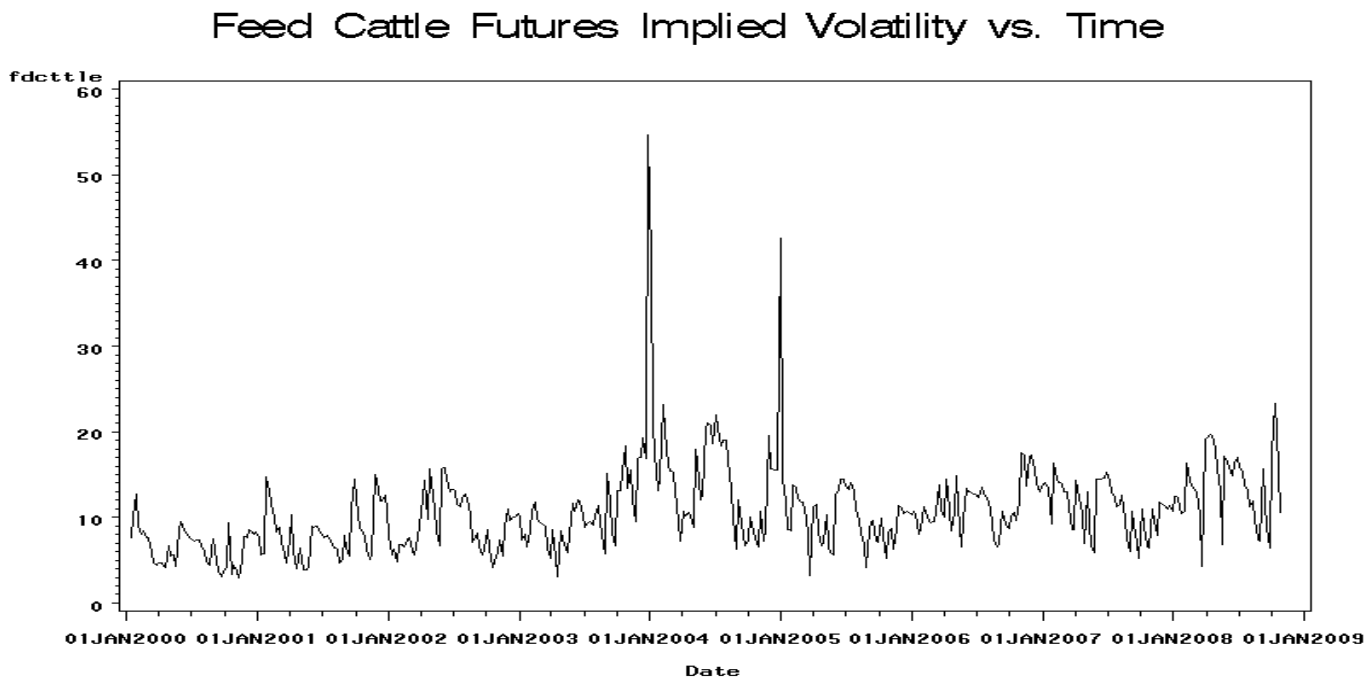

Live Cattle Futures Prices Volatility vs. Time
lcttle
50
40
30
20
10
0
01JAN2000 01JAN2001 01JAN2002 01JAN2003 01JAN2004 01JAN2005 01JAN2006 01JAN2007 01JAN2008 01JAN2009
Date

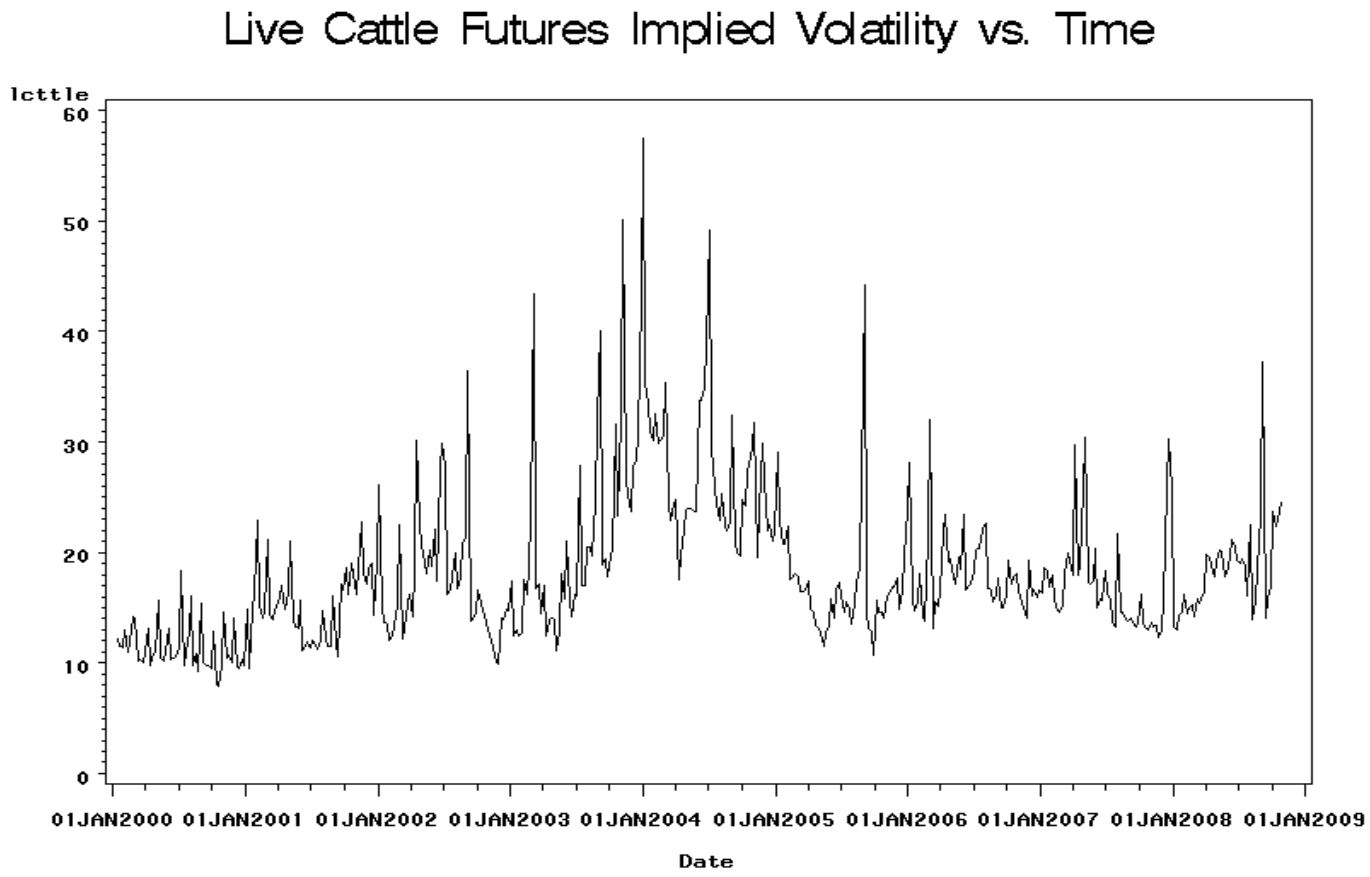
Appendix 3


Corn Futures Implied Volatility vs. Time
corn
70
60
50
40
30
20
10
01JAN2000 01JAN2001 01JAN2002 01JAN2003 01JAN2004 01JAN2005 01JAN2006 01JAN2007 01JAN2008 01JAN2009
Date

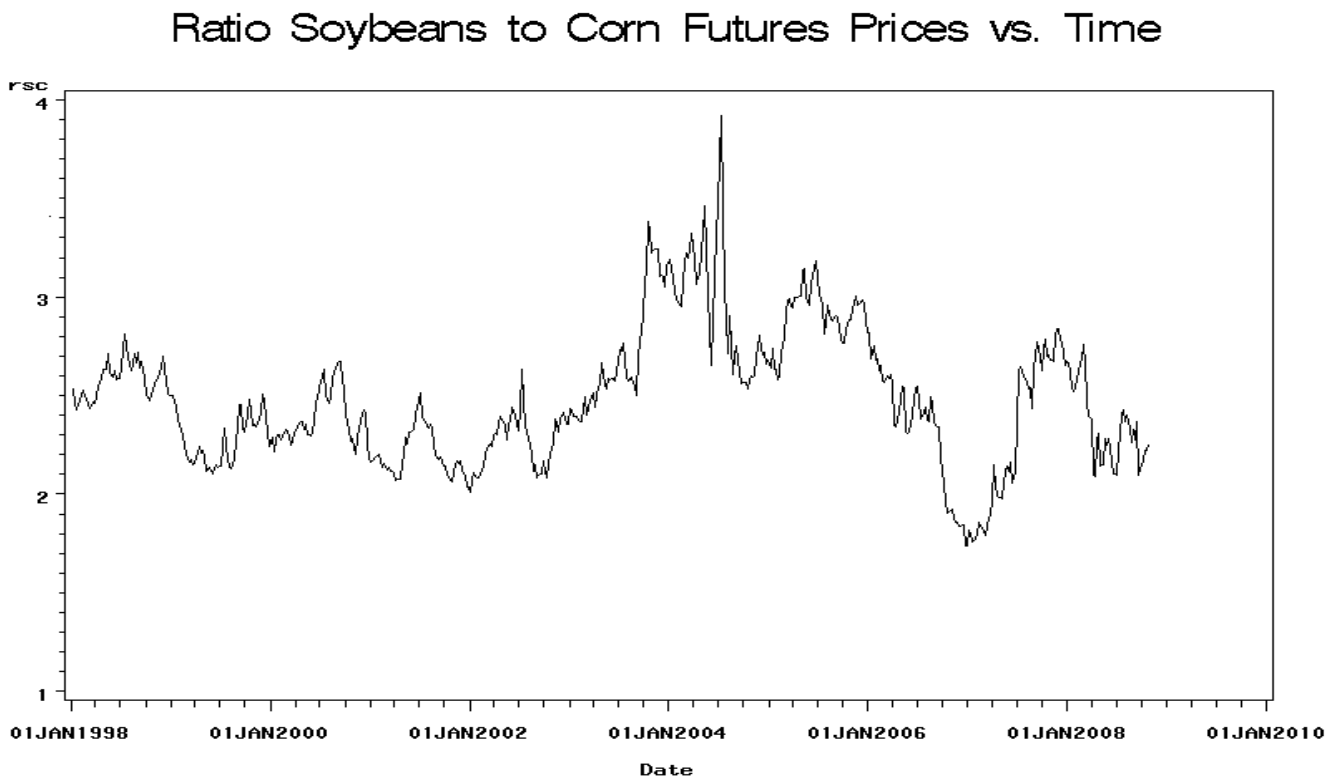

Soybean Futures Implied Volatility vs. Time
sybn
60
50
40
30
20
10
0
01JAN2000 01JAN2001 01JAN2002 01JAN2003 01JAN2004 01JAN2005 01JAN2006 01JAN2007 01JAN2008 01JAN2009
Date

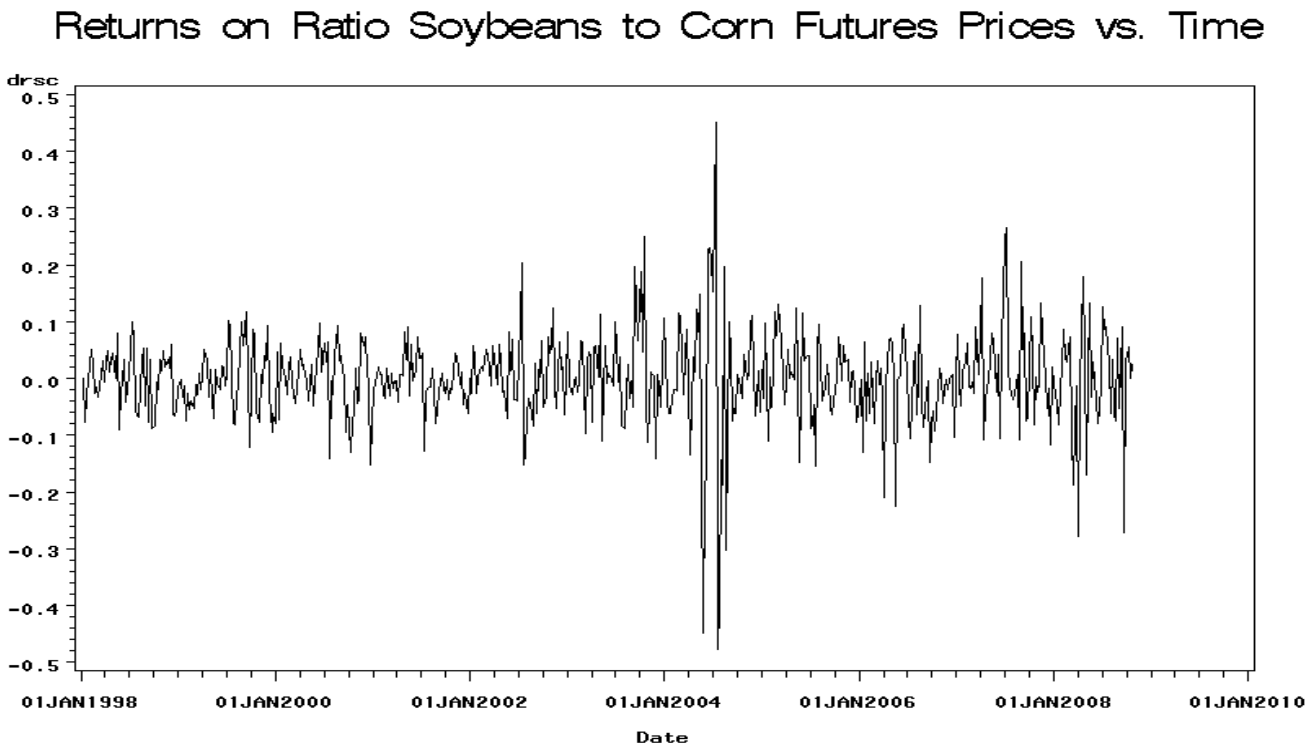
Appendix 3


Feed Cattle Futures Implied Volatility vs. Time
fdcttle
60
50
40
30
20
10
0
01JAN2000 01JAN2001 01JAN2002 01JAN2003 01JAN2004 01JAN2005 01JAN2006 01JAN2007 01JAN2008 01JAN2009
Date


Live Cattle Futures Implied Volatility vs. Time
lcttle
60
50
40
30
20
10
0
01JAN2000 01JAN2001 01JAN2002 01JAN2003 01JAN2004 01JAN2005 01JAN2006 01JAN2007 01JAN2008 01JAN2009
Date

Appendix 4

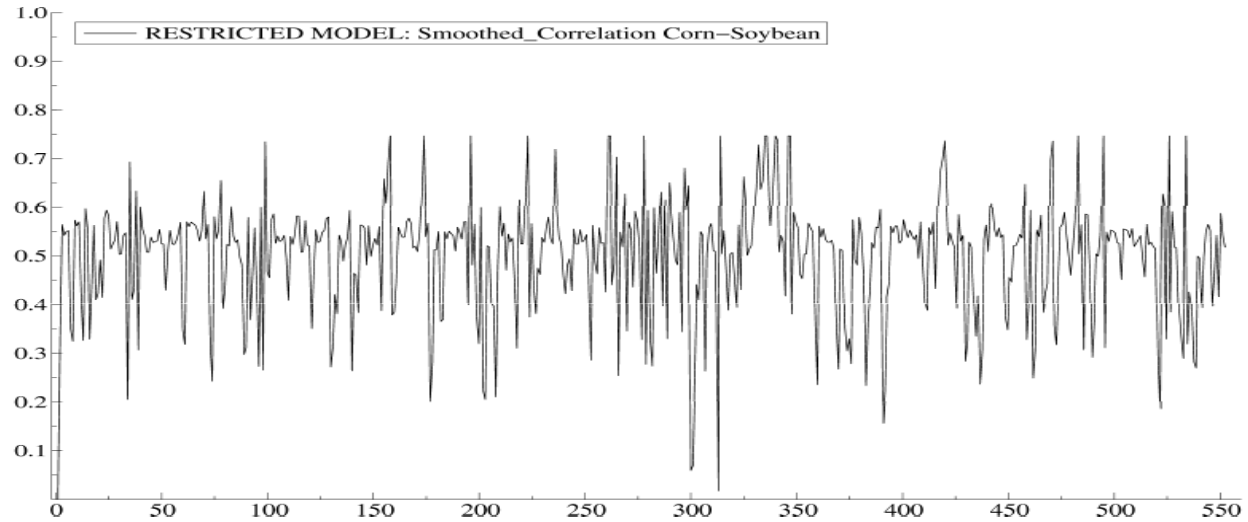


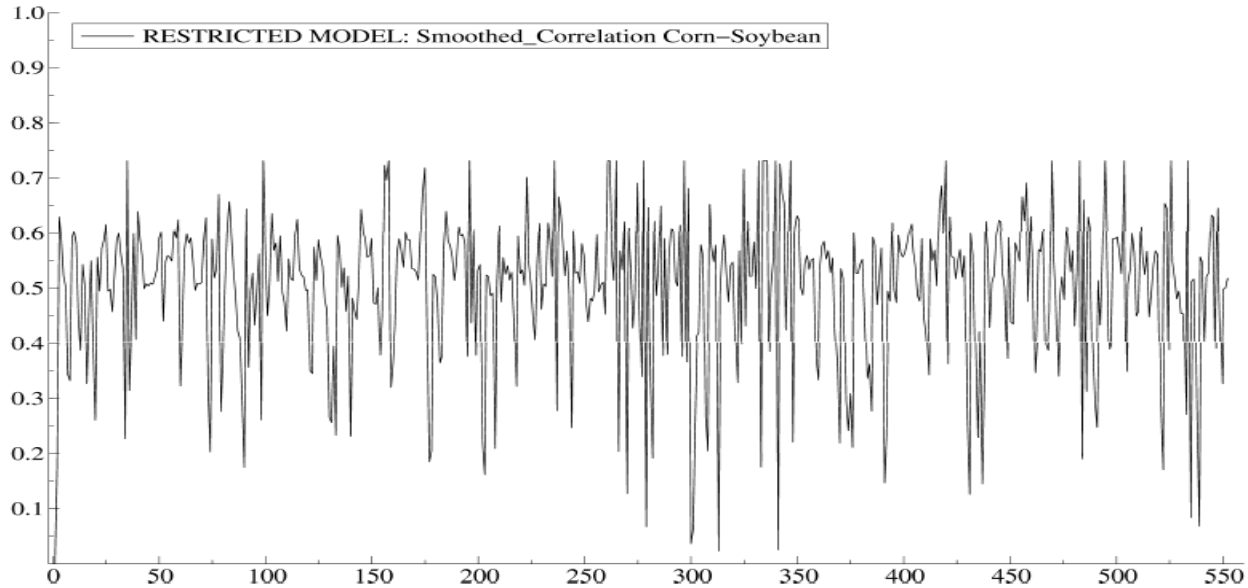


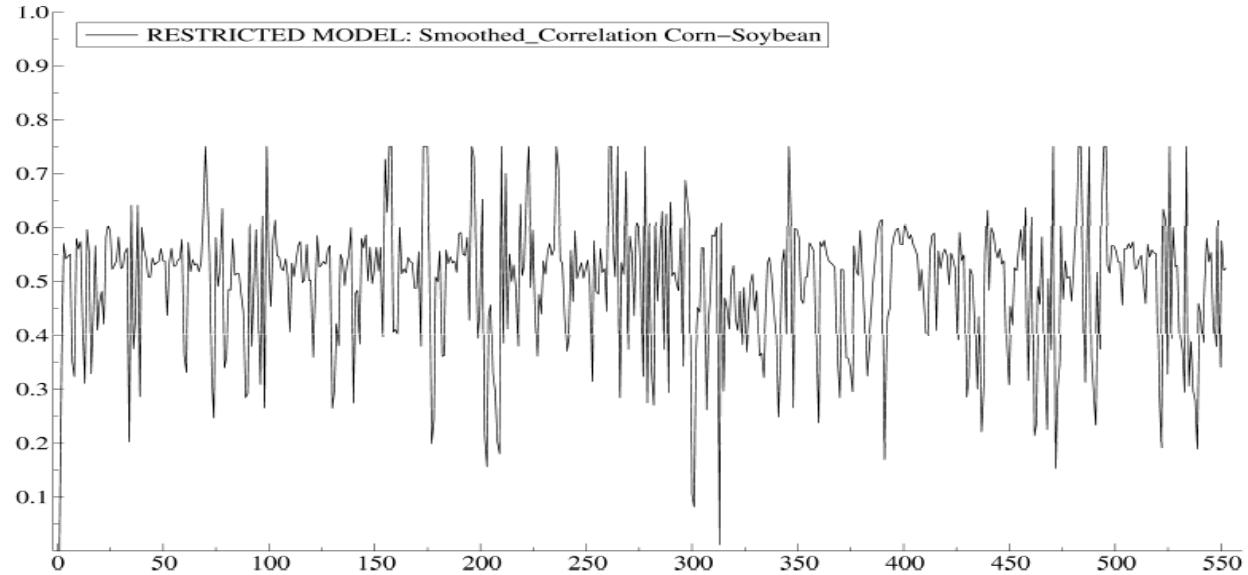
*The Returns here have been monotonically transformed using logarithm.

Appendix 5.
Jan 98 - Oct 08

Corn & Soybeans Correlations – 3 Cases of Transition Probabilities

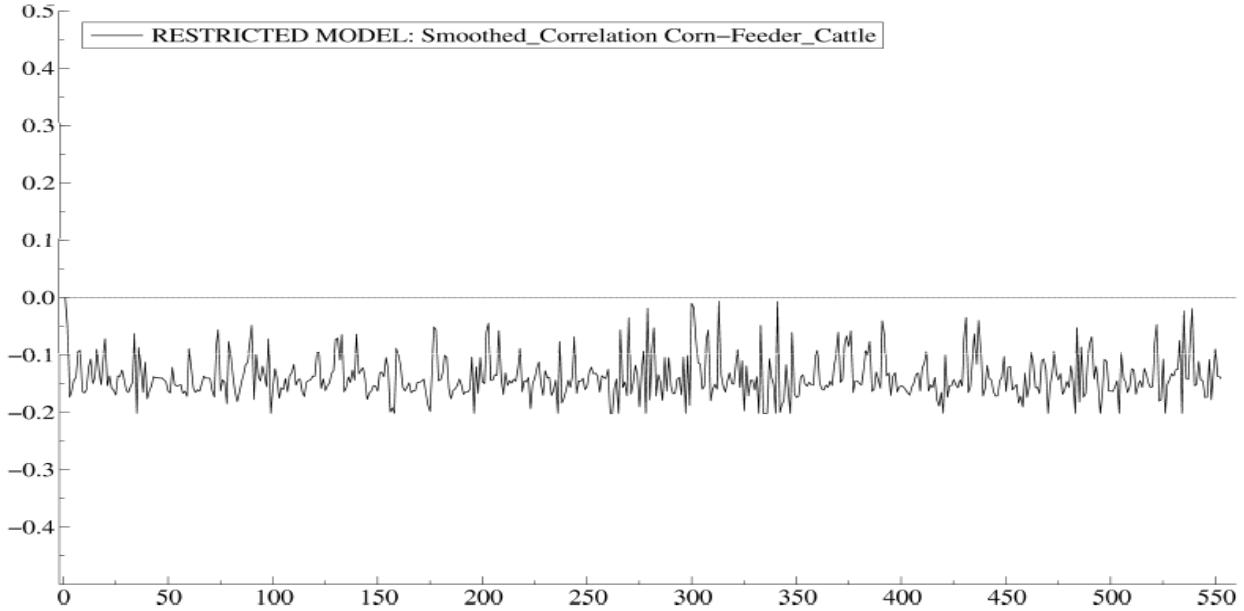


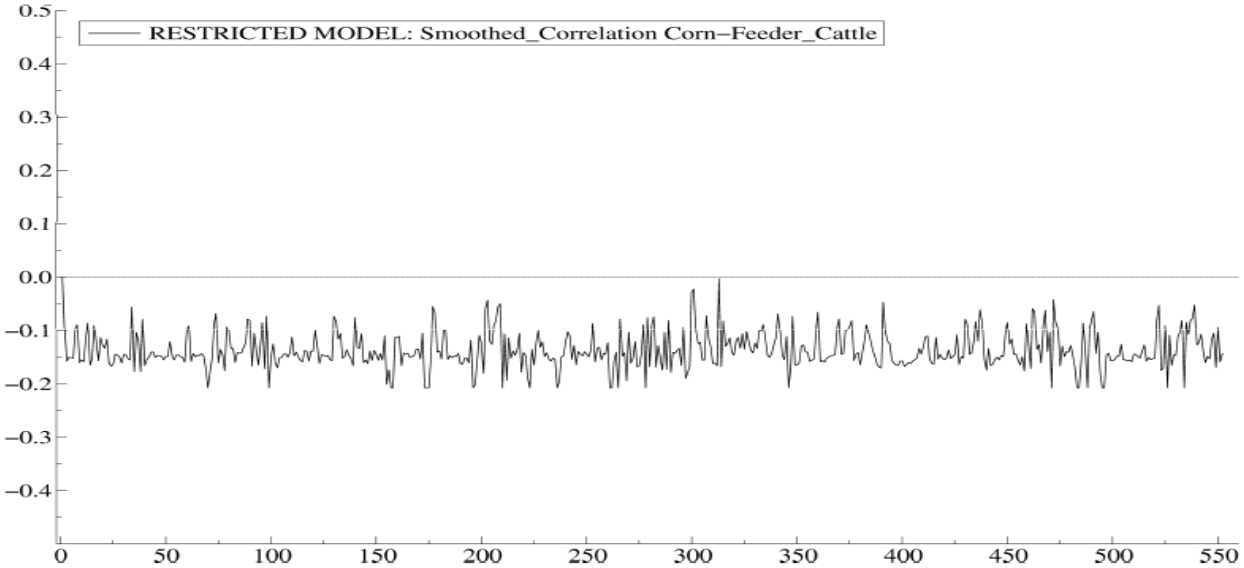


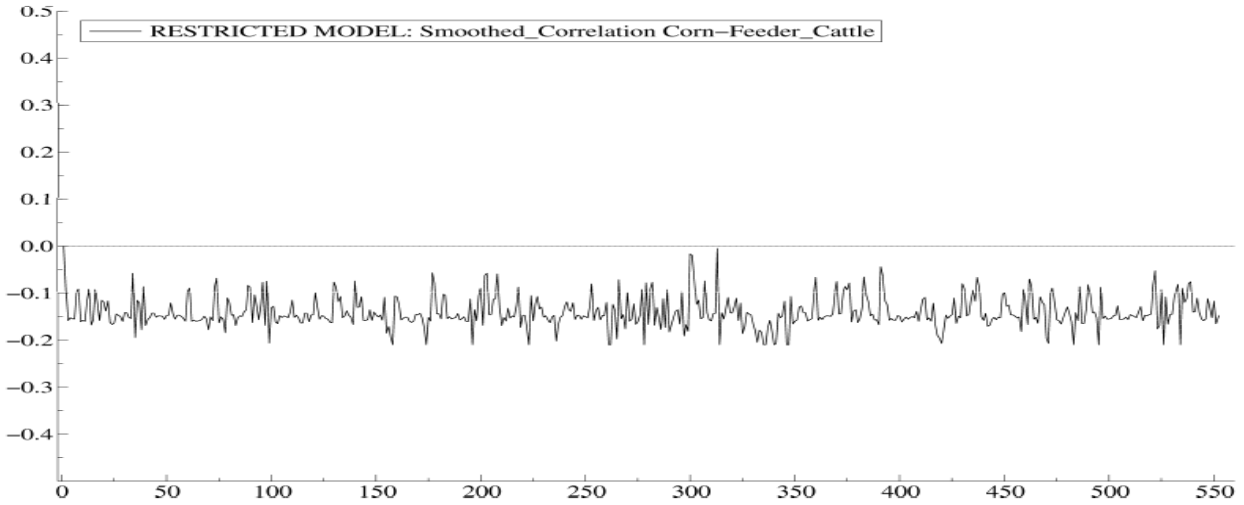


Appendix 5.
Jan 98 - Oct 08

Corn & Feeder Cattle Correlations – 3 Cases of Transition Probabilities

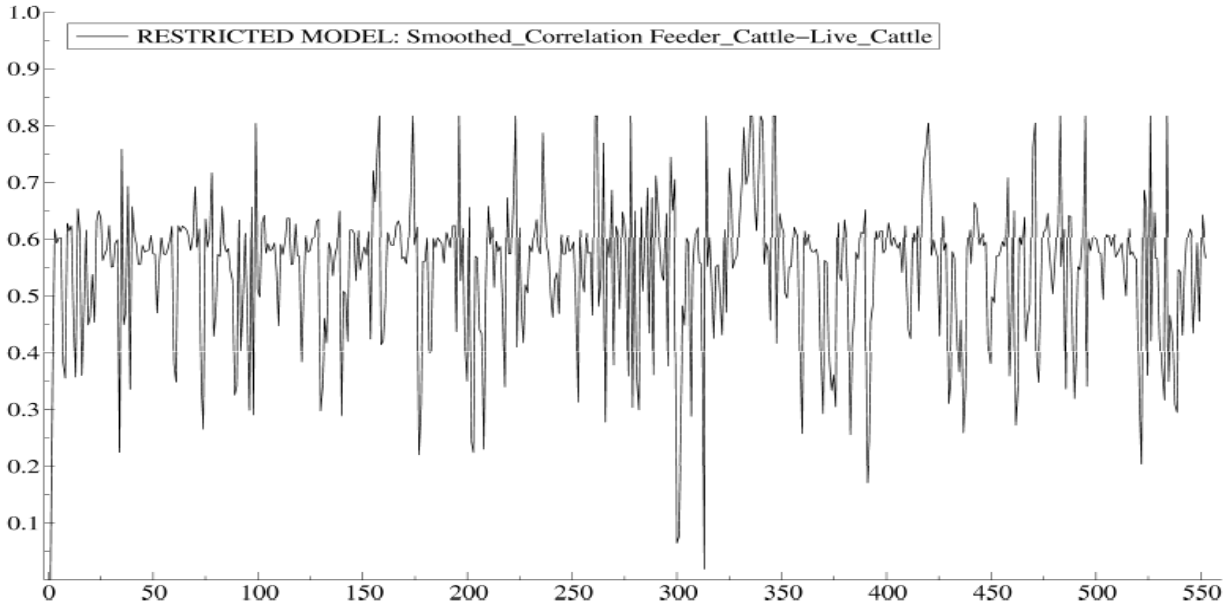


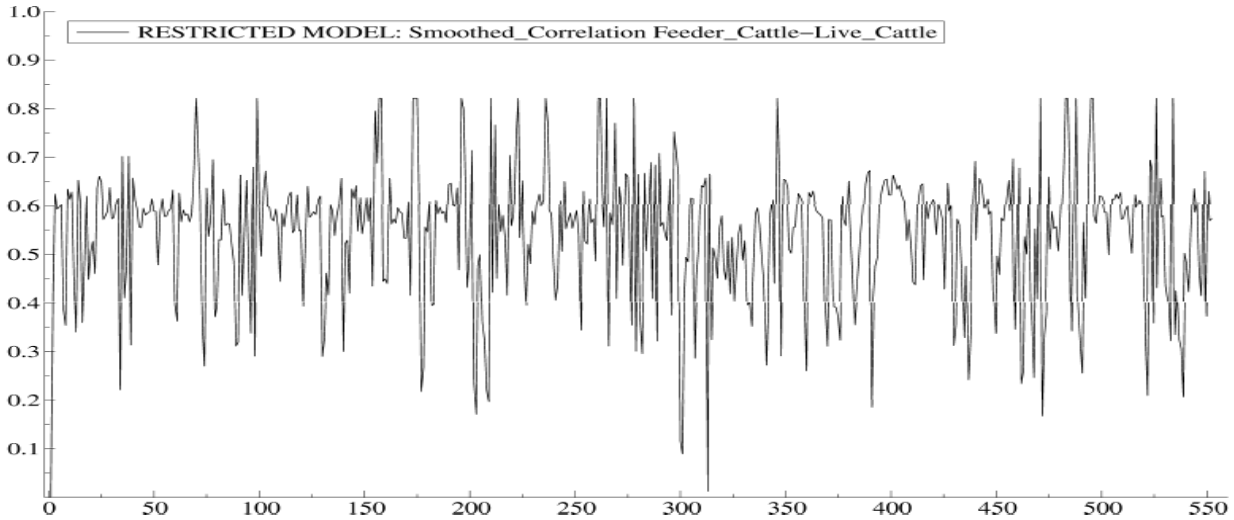


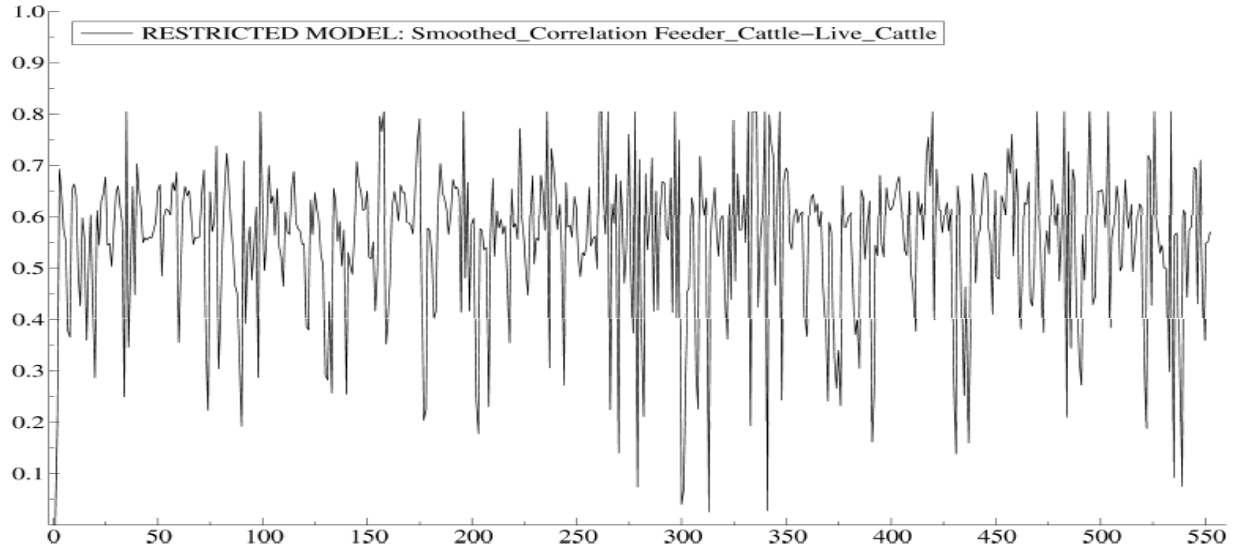


Appendix 5.
Jan 98 - Oct 08

Feeder Cattle & Live Cattle Correlations – 3 Cases of Transition Probabilities

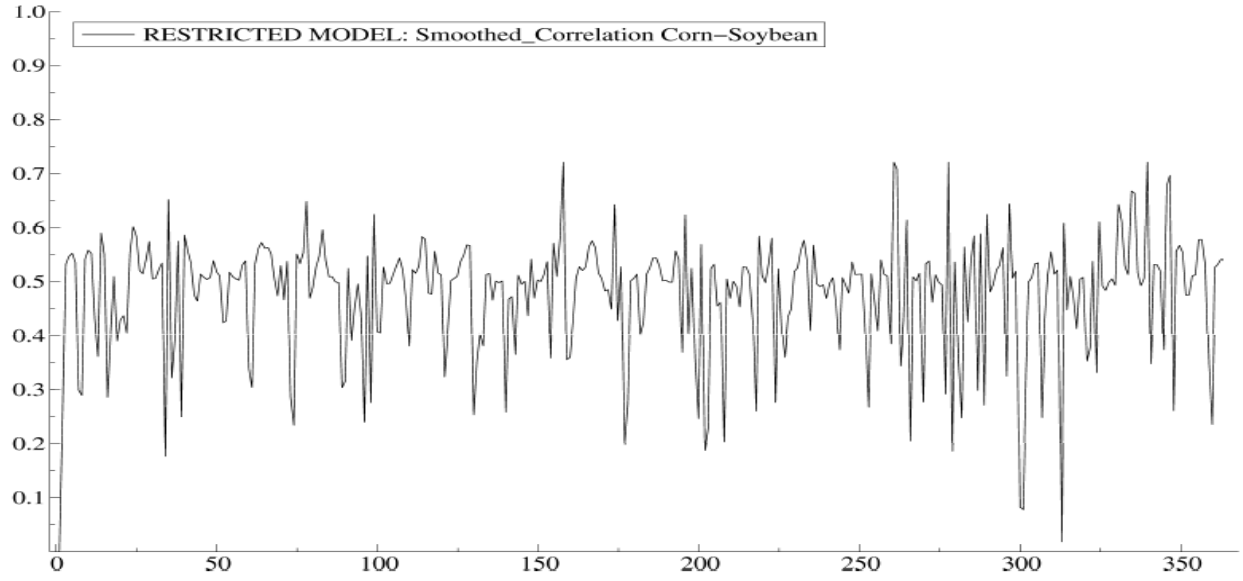


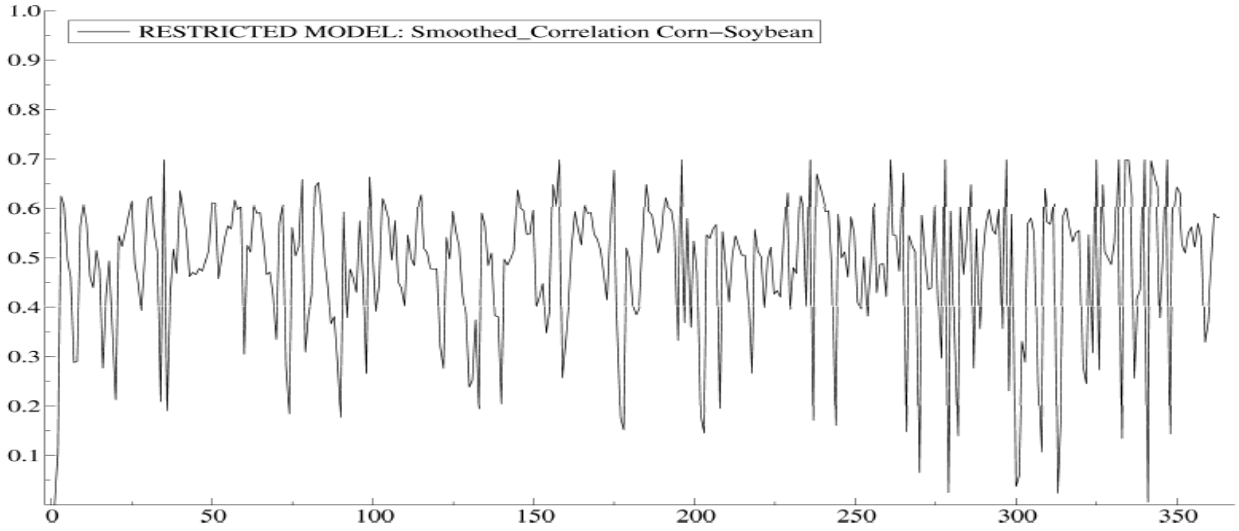


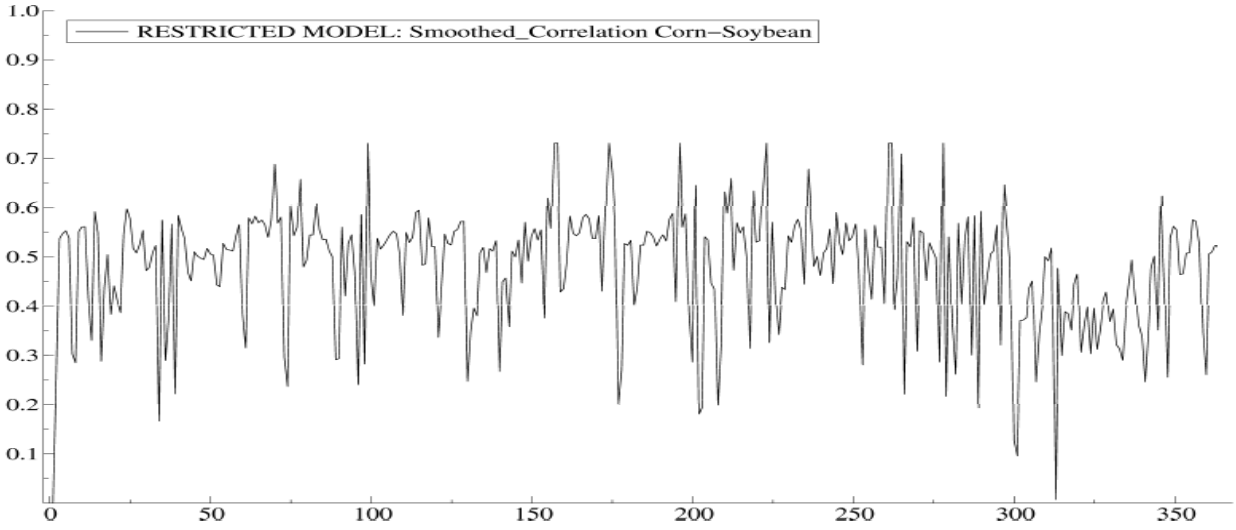


Appendix 6.
Jan 98 - Dec 04

Corn & Soybeans Correlations – 3 Cases of Transition Probabilities

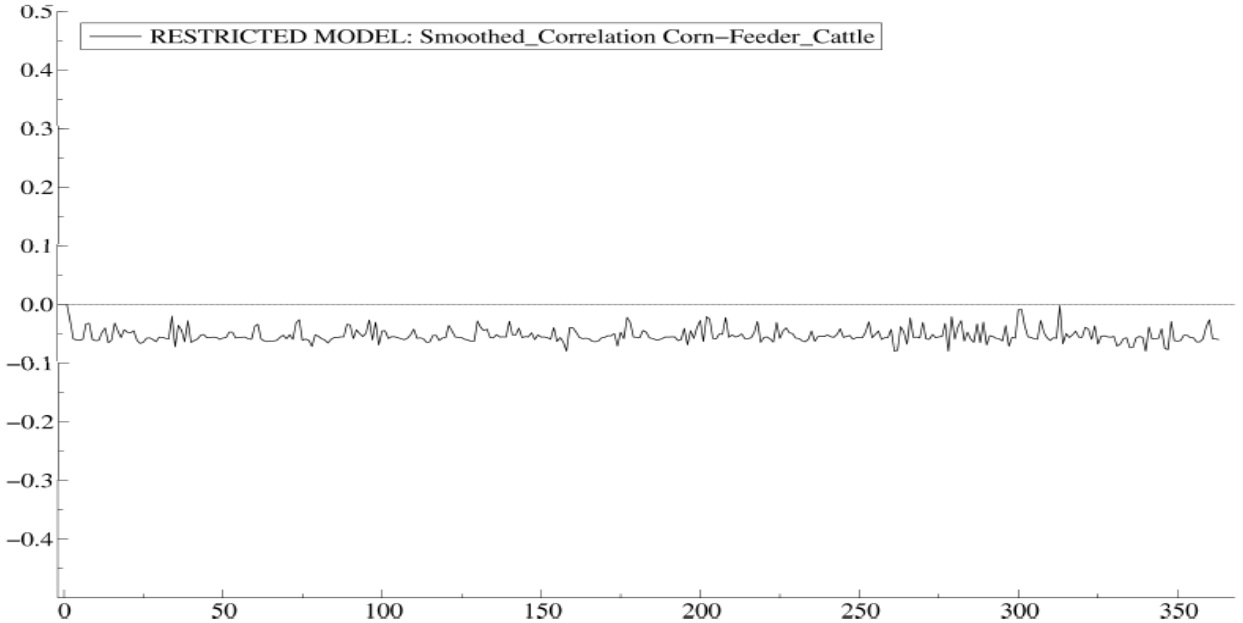


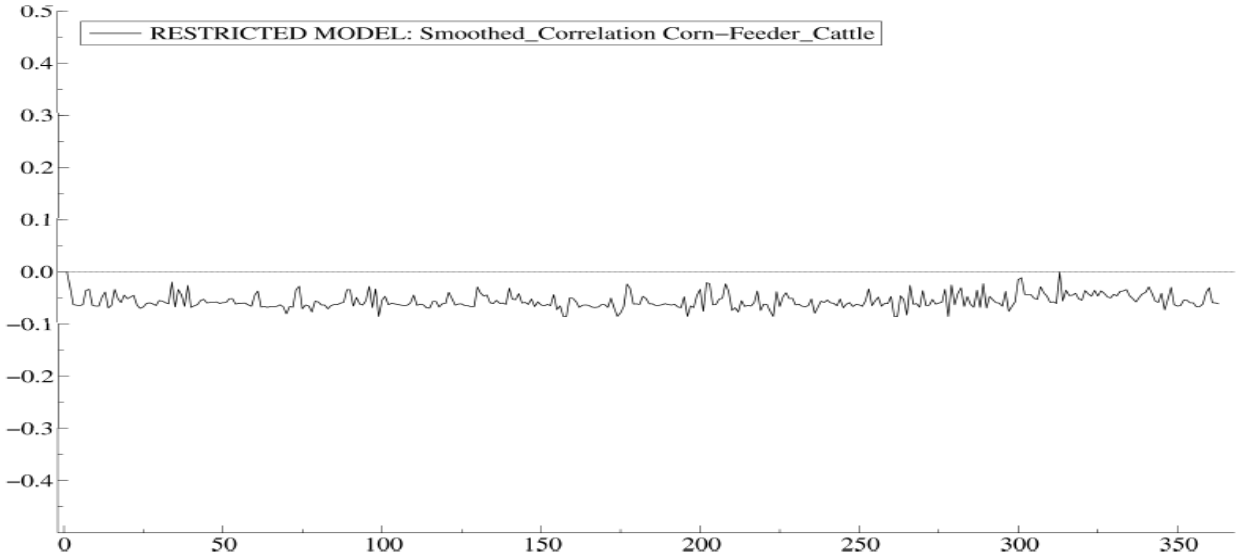


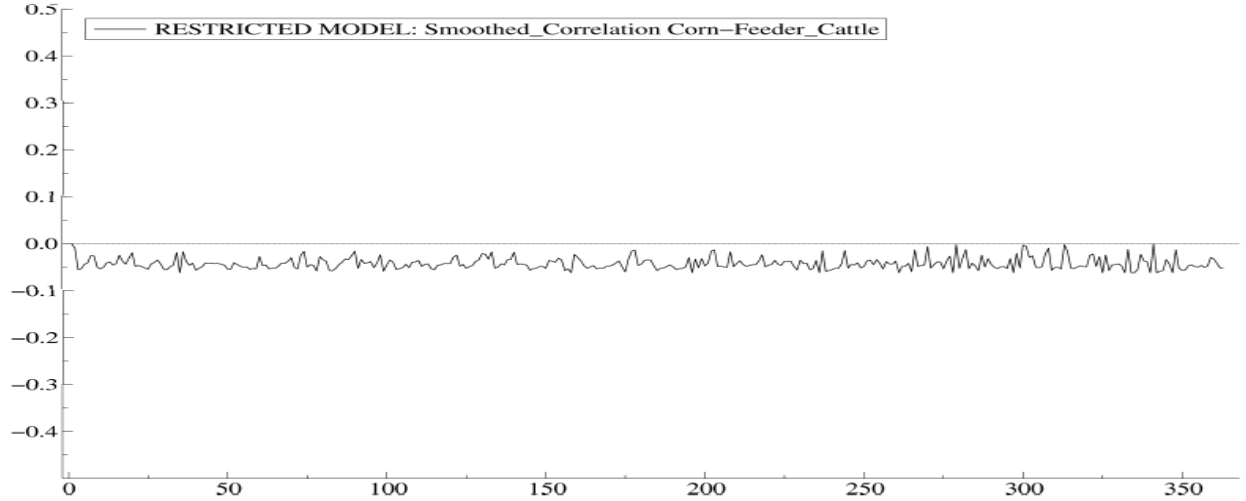


Appendix 6.
Jan 98 - Dec 04

Corn & Feeder Cattle Correlations – 3 Cases of Transition Probabilities

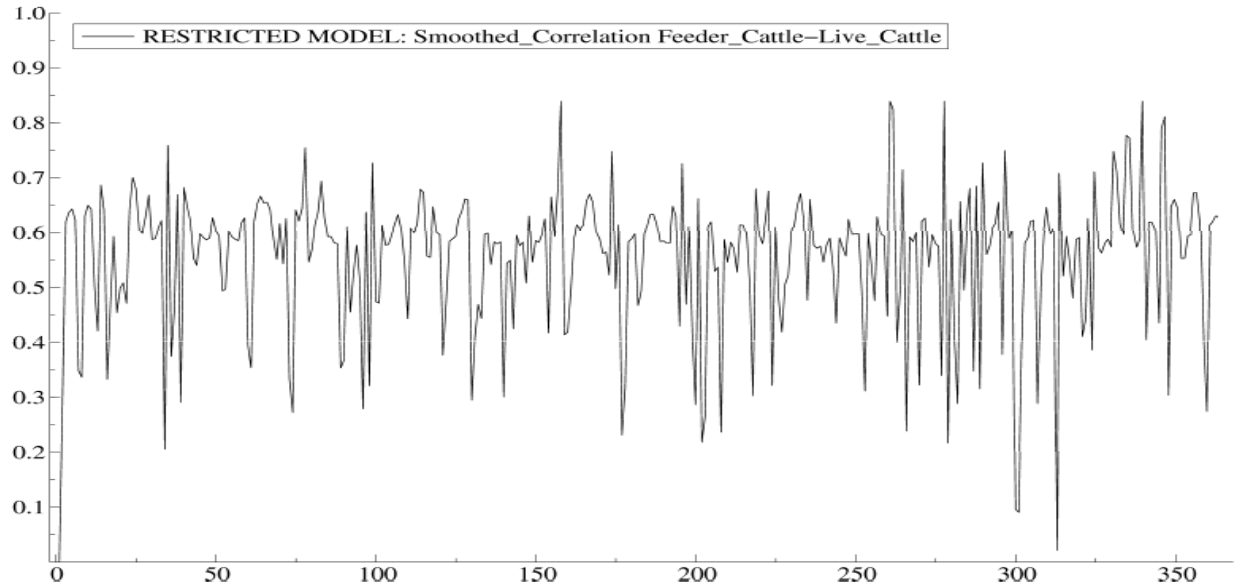


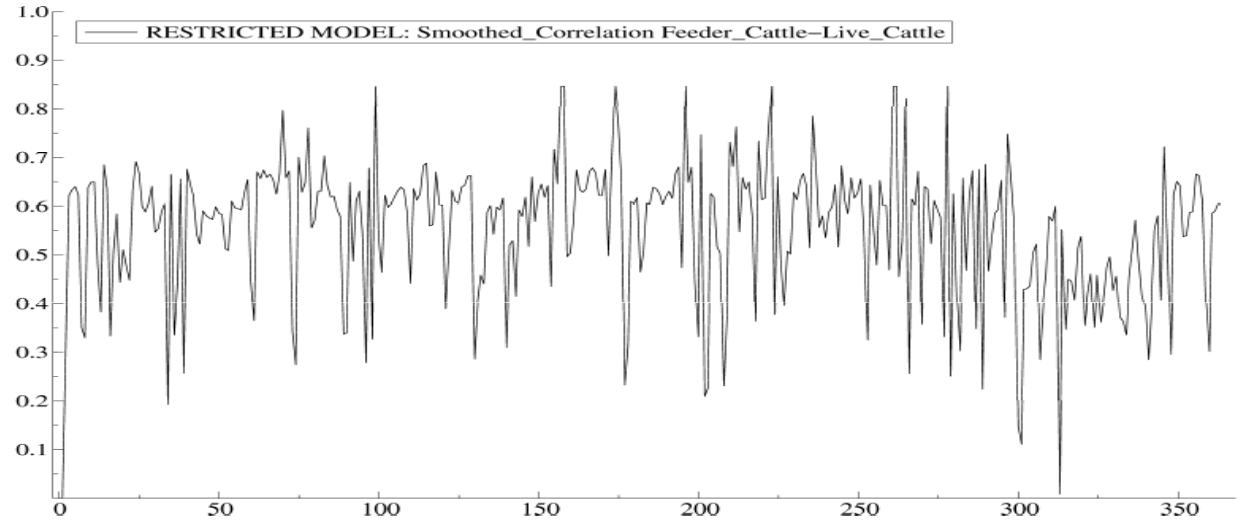


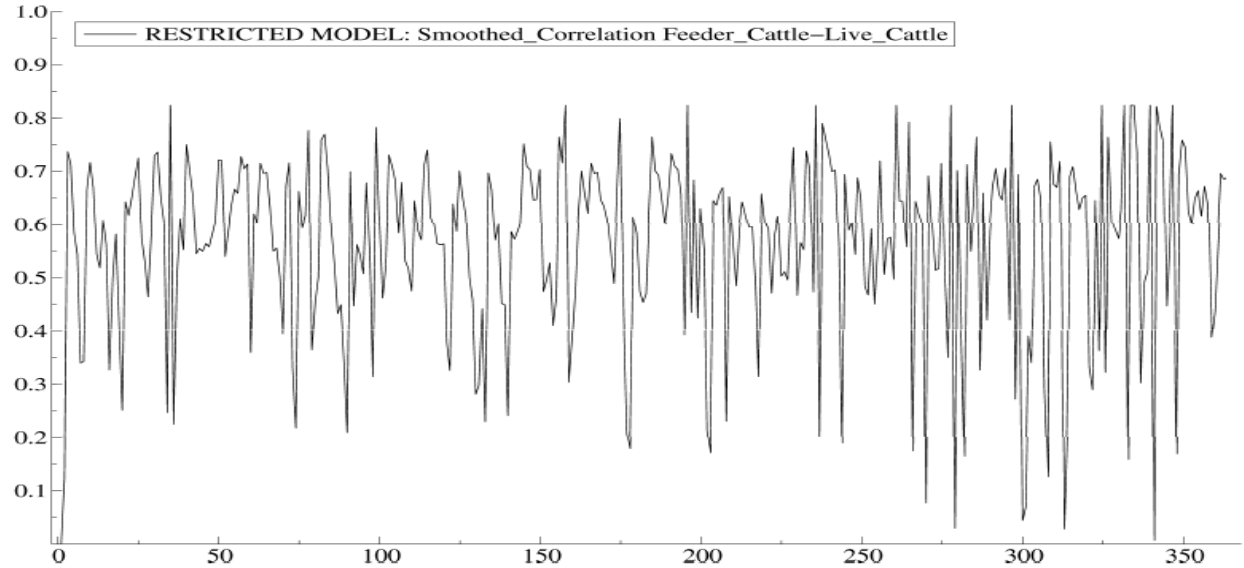


Appendix 6.
Jan 98 - Dec 04

Feeder Cattle & Live Cattle Correlations – 3 Cases of Transition Probabilities

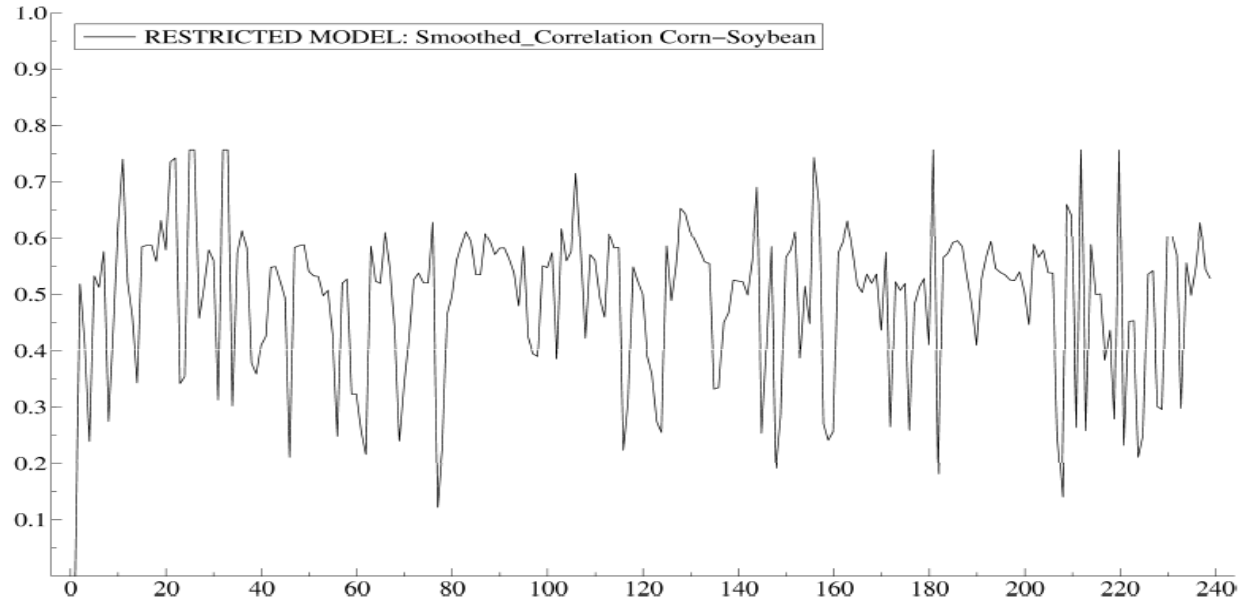


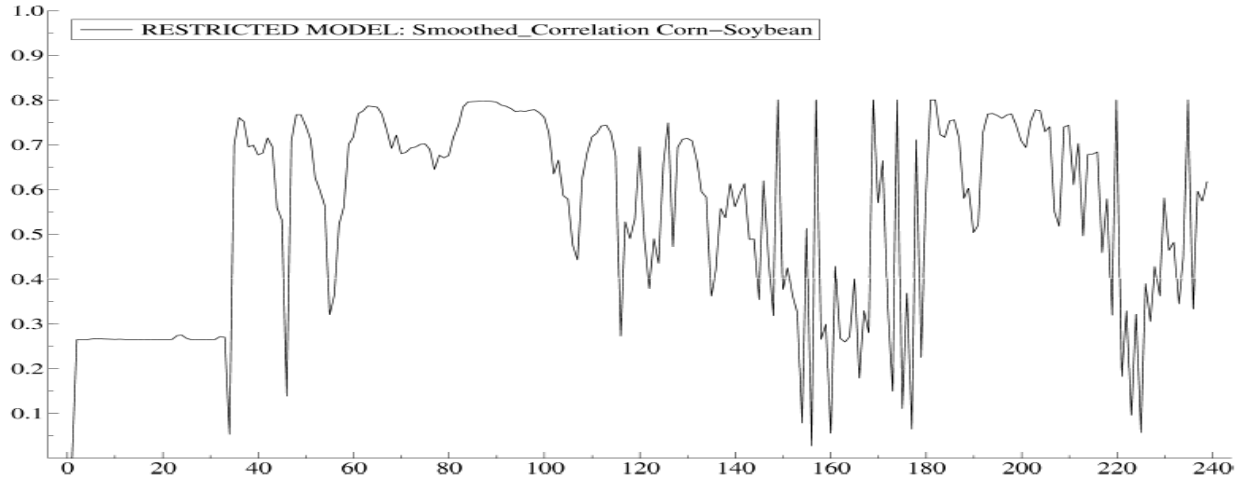


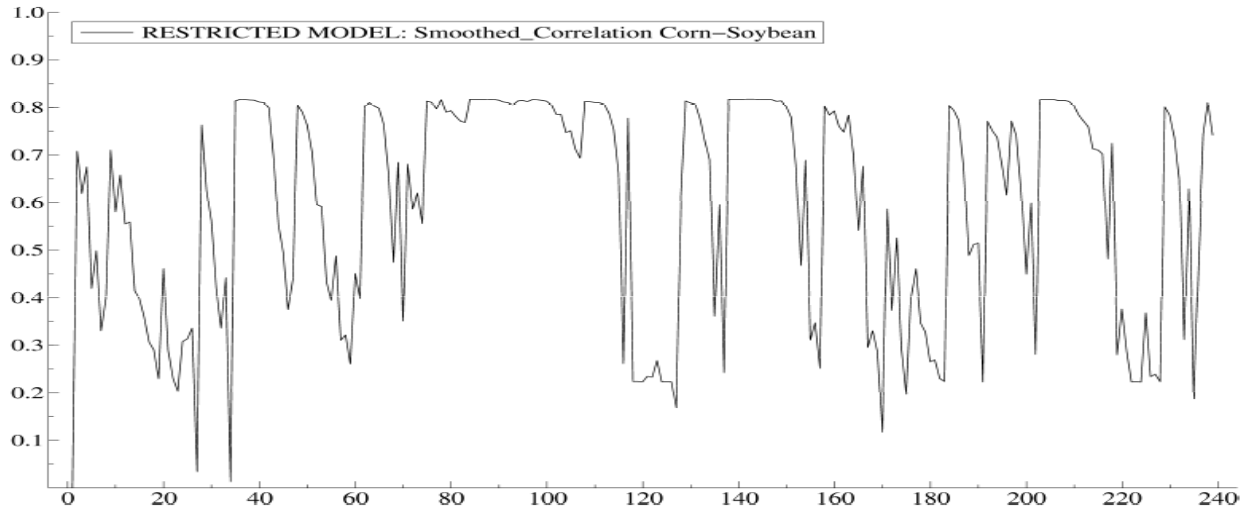


Appendix 7.

Corn & Soybeans Correlations – 3 Cases of Transition Probabilities

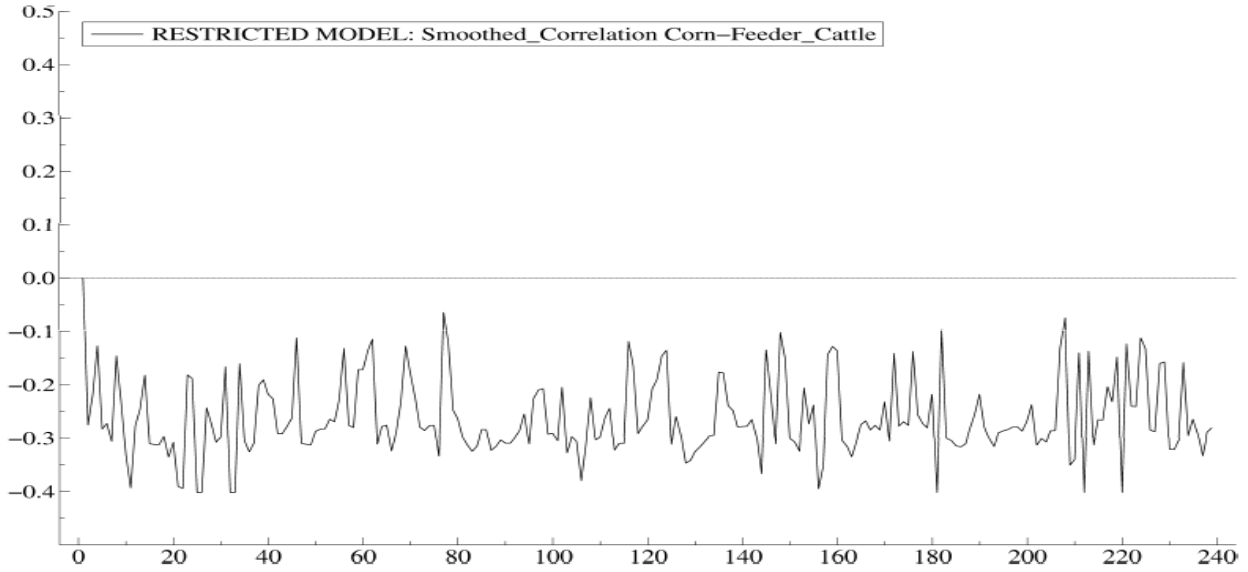


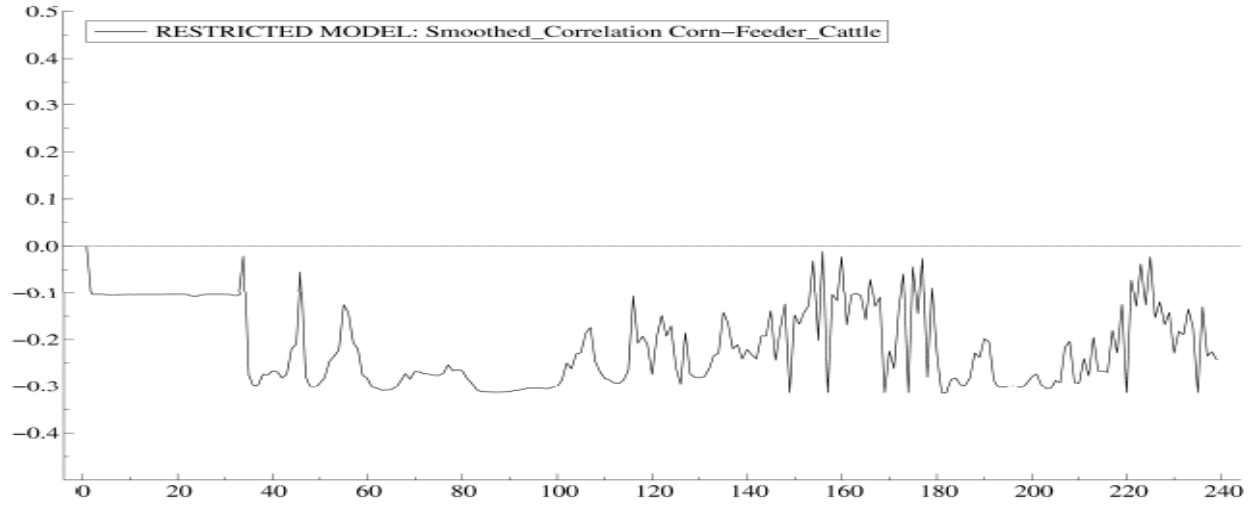


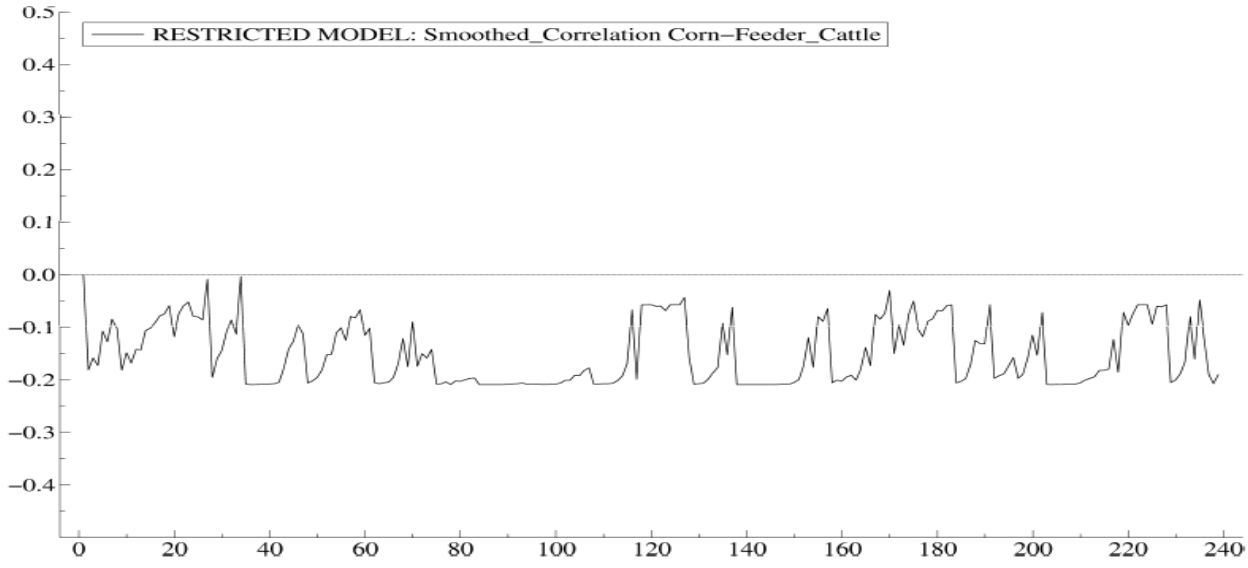


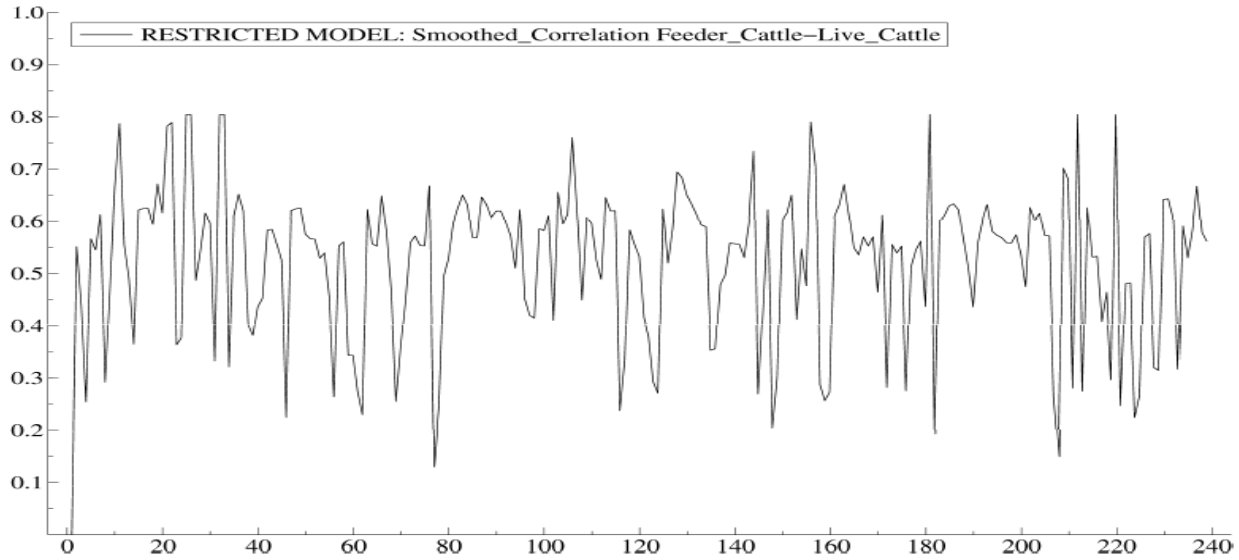
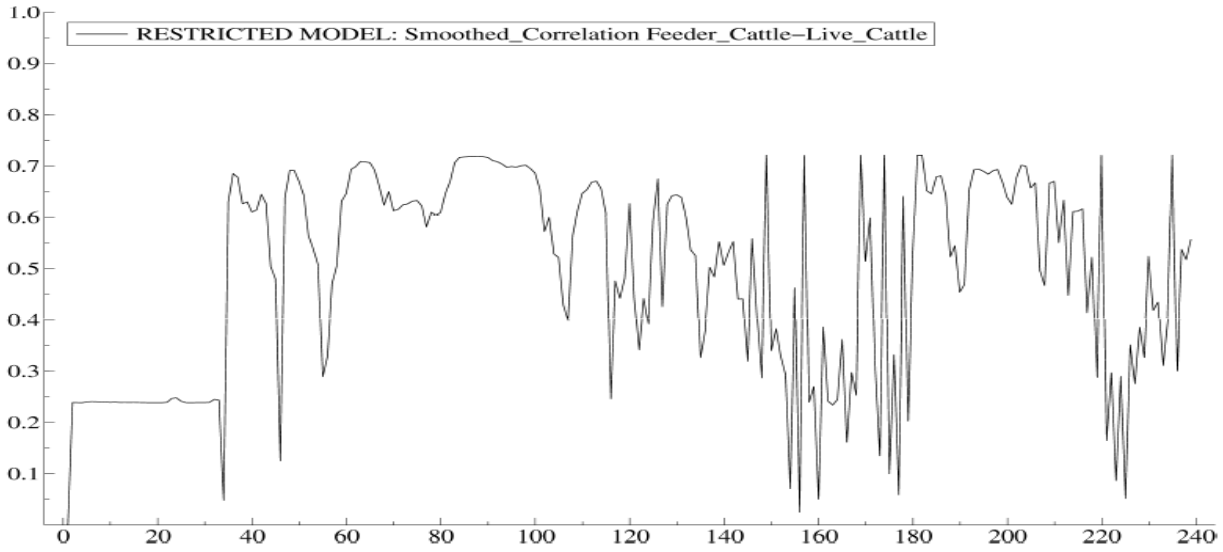
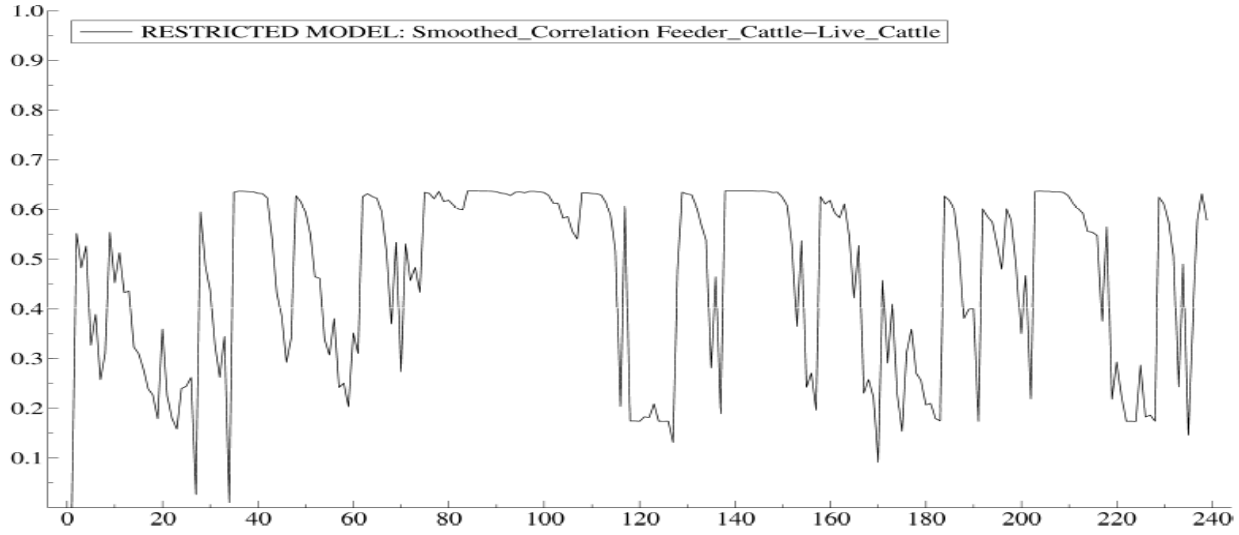
Appendix 7.
Jan 04 - Oct 08

Corn & Feeder Cattle Correlations – 3 Cases of Transition Probabilities







Appendix 7.
Jan 98 - Oct 08

Feeder Cattle & Live Cattle Correlations – 3 Cases of Transition Probabilities